This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

3 3433 06635816 3

VDA
Society

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

TRANSACTIONS FOR 1884.

E. & F. N. SPON, 125, STRAND, LONDON.
NEW YORK: 35, MURRAY STREET.
1885.

VDA

-6302-

PREMIUMS FOR 1884.

At a meeting of the Society, held on February 2nd, 1885, a Premium of Books was awarded to:

ADAM CYRUS ENGERT, for his Paper on "The Defects of Steam Boilers and their Remedy."

And to:

JOHN CORRY FELL, for his Paper on "Soft *versus* Hard Water for Manufacturing Purposes."

CONTENTS.

PAGE

INAUGURAL ADDRESS OF THE PRESIDENT. ARTHUR RIGG 1

THE DEFECTS OF STEAM BOILERS AND THEIR REMEDY. BY A. C. ENGERT 25

AN INTERNATIONAL SYSTEM OF MARINE COURSE SIGNALLING. BY CAPT. WM. B. BARKER, U.S.A. 47

THE ENGINEERING OF MALTING. BY H. STOPES 65

SOFT *versus* HARD WATER FOR MANUFACTURING PURPOSES. BY J. C. FELL 103

VACATION VISITS 119

MODERN BRONZE ALLOYS FOR ENGINEERING PURPOSES. BY PERRY F. NURSEY, VICE-PRESIDENT 127

COOPER'S COAL-LIMING PROCESS. BY PROFESSOR J. ALFRED WANKLYN 167

THE BLOWPIPE-FLAME FURNACE. BY A. C. ENGERT 185

SOCIETY OF ENGINEERS.

ESTABLISHED MAY, 1854.

COUNCIL AND OFFICERS FOR 1884.

Council.

President.—ARTHUR RIGG.

Vice-Presidents.—FREDERIC E. DUCKHAM. CHARLES GANDON. PERRY F. NURSEY.

ROBERT BERRIDGE.
THOS. HY. HOVENDEN.
ARTHUR F. PHILLIPS.
HENRY ROBINSON.
WM. SCHÖNHEYDER.
JOHN WADDINGTON.
ARTHUR T. WALMISLEY.
JOHN OGLE TARBOTTON.

Members of Council, ex-officio.

Past Presidents .. .. JABEZ CHURCH. CHARLES HORSLEY. JOSEPH BERNAYS. ROBERT PAULSON SPICE. THOMAS CARGILL. VAUGHAN PENDRED.

Past President, and one of the Founders of the Society .. .. .. HENRY PALFREY STEPHENSON.

Hon. Secretary, and Treasurer.—ALFRED WILLIAMS.

Auditor.—ALFRED LASS.

Secretary.—CHARLES JULIAN LIGHT.

Bankers.—MESSRS. LLOYDS, BARNETTS, & BOSANQUET (LIMITED).

Hon. Solicitors.—MESSRS. WILKINS, BLYTH, & DUTTON.

OFFICES:

6, WESTMINSTER CHAMBERS, VICTORIA STREET, S.W.

PLACE OF MEETING:

THE TOWN HALL, WESTMINSTER.

1885.

TRANSACTIONS, &c.

February 4th, 1884.

INAUGURAL ADDRESS.

By ARTHUR RIGG,
President.

By favour of the Council of our Society and by your unanimous votes, it is my first pleasant duty this evening to express my grateful thanks to many friends around for my election as your President. Let me assure you that I feel deeply the honour thus conferred upon me, and you may be certain that it will be my constant endeavour to advance our mutual interests in the first place; and as far as possible to extend the usefulness and influence of the Society of Engineers.

In past years your Presidents have enjoyed most hearty co-operation from every member of the Council in their mutual work, nor have they ever sought in vain for their advice or assistance on occasions when such aid was most needed; and from my tolerably long experience of many Council meetings and not a few Presidents, it is easy to foretell the future from that which has invariably happened in the past.

But not from the Council alone does the advantage of co-operation arise, for there is no Member or Associate who cannot assist the advancement of our interests; nor, indeed, does any visitor to our meetings or excursions go away without in some degree aiding the objects all of us have in view.

I hope, therefore, nay, am sure, that you will extend to me the same kind consideration that for so many years has enabled our Society to carry on its work so smoothly and so well: and in pursuance of this end may I beg that any Member or Visitor who can find time and inclination to write even a short paper, will not fail to give us all the advantage of listening to his views. It is not necessary to bring forward great discoveries, for often an enduring interest may attach to the accurate record of observed facts, noting how they may modify or even wholly change the popular half-knowledge we call "theory."

One of the leading scientific men in the United States has truly said that "theories are the only lights by which we can penetrate the obscurity of the unknown, and they are to be valued just so far as they illumine our path. This ability to lead investigation is the only true test of any theory."

But it is to the intelligent practical observer familiar with effects, but often ignorant of their cause, that the theorist is bound to refer for testing the correctness of his ideas. Such an observer should notice where theories fail, and may for his comfort remember what has justly been remarked by a great theorist, and one of the first of living discoverers, that "anomalies may be regarded as the finger-posts of scientific research, pointing to the byways which lead to further discoveries"; and that "the more rigidly we scrutinise our received theories, and the more frankly we admit their shortcomings, the greater will be our ultimate reward. In the practical world," he says, "fortunes have been realised from the careful examination of what has been ignorantly thrown aside as refuse; no less in the sphere of science are reputations to be made by the patient investigation of anomalies."

Bearing this in mind, and remembering that engineering has grown from the construction of roads and canals, from the reclamation of land, or the formation of harbours, to embrace the highest walks of science: and that its researches extend from the constitution of matter at one end of the scale of creation, to the dynamical relations of the heavenly bodies at the other end; who shall say that there can ever be a lack of subjects to interest a Society like our own?

But let us turn aside for awhile from these interesting topics, to remember that more than thirty-one millions of seconds have passed over our heads since we listened to the most interesting address of my immediate predecessor in this chair: and, although the progress of science he so ably spread before our view has advanced with increasing rapidity, yet during the year that has gone, the hand of the destroyer has been busy in our midst—cutting down impartially the rich and the noble, the man of science, and the unlettered boor.

The parent and head of all scientific associations is the Royal Society of England. Once it was the only associated exponent of ideas now published by many learned Societies, and in reminding you of the death of its accomplished and courteous
nt, Mr. William Spottiswoode, we have not only lost a
rare scientific attainments, but one who illustrated a
rly English class, namely, the wealthy man of business
g money and time to the advancement of pure science.

We must next remember the loss of our esteemed Honorary Member, Sir William Siemens, whose unexpected death occurred in November last. Many now present will call to mind the kindness with which he showed our Society over his extensive telegraph works in 1879, and then entertained us on board the magnificent telegraph steamer, the *Faraday*, where the cable between Brest and New York was being packed.

There have been many men of purely scientific attainments among us, and many practical engineers, and men of business aptitude, too, who are neither engineers nor men of science; but the late Sir William Siemens combined the three qualifications in a singularly high degree. He has been called an "inventor," but are not his contrivances better described as the successful application of a sound judgment to the necessities of a manufacture, rather than an unreasoning inspiration like inventive genius? What could be more sensible than to copy the action of the lung passages in his regenerative furnace, or what more simple than the mixing of cast iron and hæmatite ore to produce steel? and yet one idea comes from the perfect works of nature, and the other follows on the lines of Sir Henry Bessemer's splendid discovery—one appreciably extends the duration of our coal supply, and the other has revolutionised the iron trade of all countries. Too often science is blamed as a hard unfeeling mistress, who gives no rewards to her votaries; and our late distinguished Honorary Member has done one amongst his many services, in taking away some of this reproach upon her glorious name.

It will be well to mention in this place that we are greatly indebted to Lady Siemens for having sent a very handsome collection of Scientific and Engineering Books as an addition to our library, and as a memento of her late husband's connection with the Society of Engineers.

We have also to chronicle the death of Mr. Joseph Westwood, head of the firm of Westwood, Baillie and Co., of Millwall; and of Mr. W. Rumble, Engineer of the Vauxhall and Southwark Waterworks Company, both Life Members.

One other name should not be omitted from this list, although the bearer of it was not a member of our Society,—I mean the late Earl Grosvenor, eldest son and heir to the Duke of Westminster, who died after a few days' illness at the close of last month.

From his earliest childhood he took the deepest interest in matters relating to engineering, and, while residing at Calveley, was constantly to be found in the railway works at Crewe, visiting neighbouring mills, or on locomotives running between that station and Chester. Taking little interest in politics or

public affairs, the deceased nobleman was never so happy as when interested in his favourite mechanical pursuits.

Meeting here in Westminster, the metropolis of English engineering, we cannot withhold an expression of sympathy with the loss of one, who was essentially a mechanical engineer in everything but name.

This is the thirtieth year of the existence of our Society, and we have no reason to complain of its want of activity, of its financial position, or of its general progress. Since our corresponding meeting in 1883, there have been added thirty-one new members to our roll; and we have made a great improvement in the accommodation for our meetings. This beautiful Hall is in every way most admirably adapted for the purpose, and those who recollect our last meeting in December, when every seat was occupied, and hardly standing room could be obtained, will appreciate the improvement; and, for a great wonder, the problem of good ventilation seems to have engaged the attention of the architect, with sufficient success to render desirable further attention on a subject so generally neglected.

Many papers possessing considerable interest have been read during our last year's meetings; and as these will appear in the Transactions, it is only necessary now to allude to those which have gained premiums for their authors.

Mr. Bower brought before us an interesting example of synthetical chemistry, in his paper on the "Bower-Barff Process for Preserving and Ornamenting the Surfaces of Iron and Steel." An observation was made by Dr. Percy, that Russian sheet iron resists rusting where covered by a thin coating of magnetic oxide through some accidents in the process of its manufacture. Acting on this hint, Professor Barff succeeded in producing this Fe_3O_4 artificially, by subjecting iron to steam, superheated to such a degree as to set paper alight. A similar result was produced by Mr. Bower and his son, after a weary series of experiments, by reducing common rust or the sesquioxide of iron Fe_2O_3 into the hard black glaze of magnetic oxide.

Both of these inventions are now worked under one management, and seem to have originated a new industry which admits of considerable expansion.

They also form an admirable illustration of the value of apparently trifling observations, and serve to show that if in a ion on any paper, any Member brings forward a seemingly icant circumstance that has fallen under his notice, it

may become a seed destined to develop into an important plant.

Another premium was awarded to Mr. Chris Anderson of Leeds, for a paper describing his ingenious proposals for the construction and establishment of deep-sea lighthouses as mid-ocean stations, for meteorological observations on travelling storms, and to forward intelligence of passing vessels.

Mr. Hamilton W. Pendred gave us a paper on "Designs, Specifications, and Inspection of Ironwork." The author pointed out how it sometimes happened that unpractical or impracticable directions were given to contractors by those who drew out specifications, and were unfamiliar with the necessities of manufacturing requirements. Illustrations, taken from wrought-iron girder work, were given in support of these views, with practical suggestions for the removal of such anomalies.

The interesting visits of the season when no papers are being read, have taken place as usual at the close of the last session; and we visited in succession the Great Western Railway Works at Swindon on the 27th June; the Thames Ironworks and Gas-Light and Coke Company's Works at Beckton, on the 18th July; and the Locomotive Works of the London, Brighton and South Coast Railway Company at Brighton, on the 23rd August. At all these places there were numerous subjects of great interest to mechanical engineers; and we owe many thanks to the gentlemen who met us at the different works, and so kindly explained the things which they had to show.

But among the visits paid during the past year, an exceptional novelty attaches to the few days spent at Nottingham by members of our Council.

Through the kind invitation of Mr. Tarbotton, the consulting and water Engineer, we had an opportunity of seeing the new waterworks of that enterprising town, in their then interesting and instructive state of construction. Afterwards we inspected the old waterworks, and were most hospitably entertained in the handsome engine room by the Mayor. The new gasworks next claimed our notice, and, when finished, they will contain the largest single retort house which has hitherto been built, with every appliance also for a first-class modern establishment.

After an expedition on the succeeding day to the Westwood Collieries, where an opportunity was given for seeing coal-getting on the long-wall system, we were shown over Sir James Oldknow's lace mill, with the work carried on therein, which was about the greatest possible contrast to a coal pit and its surroundings.

In the manufacture of lace, there are patterns designed by an artist and then translated into a number of Jacquard perforated cards, and these again direct the manipulation of each thread of a delicate loom, and interpret the design into its original idea; but worked out in lace instead of on paper. Nothing could exceed the welcome extended towards us by all whom we met, and an accidental reunion with members of the Chesterfield and Derbyshire Institute of Mining and Mechanical Engineers, gave them an opportunity for the graceful compliment of inviting our President, in the absence of theirs, to take the chair at the dinner of both societies.

All these meetings are of extreme interest: they are carried out by many societies, and prove of great advantage as well in educational as in social value.

In some degree, meetings with our fellow engineers take the place of guilds or trades-unions which have existed from very early times; and they keep the members of different societies acquainted with the work of others, and lead to a personal interest, which may perhaps eventually work out into a common brotherhood among engineers, akin to that which our good friends the masons so admirably display among themselves.

Such interest will advance and extend, to include not only our countrymen, scattered abroad into many lands, but also those many distinguished foreigners who vie with ourselves in bringing the ample powers of nature into subjection to our use and gain.

If we glance abroad, there is much to interest, to copy, and admire; but our deepest concern must always be with those of our own race or nation in America, Australia, or India, whose undertakings are on so magnificent a scale.

The exchange of published Transactions keeps us acquainted with those lines of investigation pursued by foreign engineers; but of late years India is of all countries the one which calls for the greatest interest on the part of engineers in England.

Our colonies will doubtless in the future become more and more independent of the mother-country, and will, like America, educate their own engineers; but such a condition is not likely to prevail in India, at any rate for very many years to come. Hence there will be a constant, and, we will hope, an increasing demand for English engineers in that country, and all things concerning their progress and welfare must be matters of deep interest to us.

Until within a comparatively recent period, all civil, as well as all military engineering was carried out by that distinguished body of men, the Royal Engineers; and even now their mem[illegible] by the highest administrative posts.

From many schools, from engineers' offices, and from the great college at Cooper's Hill, numbers of young men have been drafted into India of late years to do work which was formerly required by Government from officers of the Royal Engineer Corps, whose studies had been more particularly directed to military and not civil engineering.

The innovation does not always seem to have worked smoothly, for the new-comers consider it hard that while doing similar work, they should not be treated in regard to pay and position exactly as the Royal Engineers.

But in many cases, much as one must sympathise with their feelings, the difference as to pay is simply one of contract; and when the employment of civil engineers has grown from an experiment into a permanent system, there is every reason to hope that future engineers will be able to make better terms with the Government employing them. All engineers are members of one service, and though it has two branches, military and civil, yet in a dependency like India, none can dispute the advantage of military men having a competent knowledge of civil engineering, nor of civil engineers possessing some acquaintance with defensive works, &c., nor may we blame the responsible Government for moving slowly in changing any of its established systems.

Quite until recent years, the various services in India have been recruited from men who had the education of the old English school, men of cultivated tastes, and whose habit of mind and general ideas enabled them to mix at no disadvantage with the polite and ceremonious members of that ancient, aristocratic civilisation.

None are keener-witted than the natives of India, in appreciating and respecting that "indescribable mixture of elevation of mind, correctness of taste, self-control, and decision of character," which constitutes the gentleman; but, by some people, reports have been set on foot against the new civil engineers, that in too large a proportion this description is not sufficiently exact, and it would be most unfortunate if any such statements could be substantiated. Officers in the army, and members of other professions, are collected in schools or colleges, and being associated with their equals, never lose the tone of society in which they move; but engineers labour under a great disadvantage in this respect. Isolated during their training in practical work, they are brought into direct and intimate contact with a class of artisans into whose companionship their most injudicious friends would hardly send them to learn good manners.

It is hardly a matter of surprise that some young men

unlearn for awhile their earlier cultivation, and go abroad imbued with that offensive dogmatism which is a sure sign of ignorance and a narrowed mind.

Competitive examination too has not yet proved an unqualified success; though it has opened a door of easy advancement into positions which formerly required higher qualifications than an overloaded brain. Hence it must not be supposed that any young man who gets on by making a good use of the abilities with which he is endowed, can afford to ignore the feelings, or even offend the prejudices of those into whose society he may rise, or whom circumstances may bring under his control.

It is a good thing to reflect upon a favourite maxim of the illustrious Smeaton, "that the abilities of the individual are a debt due to the common stock of public happiness and accommodation," and to remember, as *he* never failed to do, that the faithful discharge of so invaluable a trust will give to the engineer a position which none can ever take away.

We should all rejoice to learn that the civil engineers in the department of public works in India had induced the Government to improve the terms of their engagement, for it is monstrous that such a cause of jealousy should be allowed to exist between them and any branch of that gallant army through whose hold of India alone it is, that opportunity is given for the employment of English civil engineers there at all.

Each department has its own peculiar duties; and officers of the Royal Engineer Corps, while supreme in military matters in times of peace, and supreme in all in times of war, yet have no claim to superior knowledge of the details of civil engineering.

Nor have we any standing for adverse criticism of the well-considered conclusions of military officers—whether they object to a road or railway in a subject country, or point out the dangers arising from a Channel tunnel in our own.

During the past year a series of lectures have been commenced by our Society upon engineering subjects, and the sciences related thereto; and it is a matter of such great importance that instruction should be thorough and practically useful, that a few remarks upon it may not be out of place at the present time.

These lectures were never intended to be of the same class as those delivered at the Institution of Civil Engineers by distinguished leaders of scientific thought. The Council of that

great parent of engineering societies throughout the world expressly announced that their lectures were not designed as courses of instruction, but delivered to enable their members and students to know at first hand the march of scientific discovery. Those who enjoyed the privilege of listening to these lectures, will be well aware how admirably this intention was fulfilled.

Our lectures, on the contrary, are expressly given as short educational courses in complete series; and though there may be a great fascination in listening to the addresses of those familiar with the higher walks of science, yet it is unwise to pass over the paramount necessity for a good elementary knowledge as a foundation leading to a thorough understanding and appreciation of what we hear.

At the present time a course of lectures is being given in the Hall of our Society on Electrical Engineering; and in February a course of eight lectures will be given by Mr. J. W. Wilson on the important subject of General Engineering Construction, which we hope may be largely attended, for we may almost venture to say that there is no branch of mechanical engineering better worth cultivating than a knowledge or art of designing machinery.

Modern engineering is the youngest of our sciences. Such works as the great roads and bridges of Telford, the harbours of Smeaton, and the constructive details of canals and railways belong more properly to that branch of civil engineering nearest akin to architecture, and they have been undertaken by civilised nations in all historic times.

So long as the powers of wind and water alone were available for manufacturing purposes, the uncertainty and variability of the one, and generally local inconvenience in the other, rendered manufactures on an extensive scale impossible, and crippled any development of that branch of engineering which deals with motion and the application of power.

Necessity led to the invention of tools in the earliest ages, and considerable practical skill must have been acquired in their use by rude tribes whose stone or bronze implements are their only history. Even now, if we travel among the fast disappearing races which inhabit those enchanting islands which adorn the desolate Pacific, or if we become acquainted with an ancient civilised race, driven ages ago into the inhospitable north, we find implements and tools bearing a wonderful analogy to those portrayed in Egyptian tombs, or used by country millwrights of the present day.

From rude axes of stone we can trace tools through various

stages of development to the splendid machinery of modern times. The materials used in their cutting edges have run through a series from stone to bronze, from iron to steel, and even to the diamond itself; while in the means for holding such tools, wood has given way to iron or steel.

In this great chain of progress, lasting through uncounted centuries, there are gaps required to show how one tool may have gradually grown into another; but these gaps might, perhaps, be filled by diligent search. We even discover a tendency of recurrence to forgotten types, or details of construction, now as useless as the undeveloped leg bones of a whale; and in fact the great laws of development and natural selection are just as applicable to mechanical contrivances as to the growth of an animal or species.

All we need to do in order that the analogy shall be identical and the comparisons complete is to doubt the credibility of men's interference, and to assume that tools chose for themselves higher organisations, and that their existing preference for steel over stone is simply the effect of inevitable law, and thus the whole chain of reasoning becomes nothing else than one more convincing proof that all things evolve themselves!

Limits imposed by human or animal strength kept down the dimensions of ancient tools, and, as we all know, it was the invention and general use of steam power which has given an incalculable impetus to modern engineering. This has raised it from being a mere handicraft to an employment for the educated classes, and revealed its claims as a science worthy of the most enlightened intellects of our time.

This new power has increased the dimensions of machines, and so enlarged the scope of mechanical engineering that a necessity has grown for better educational appliances for teaching the fundamental laws of matter and motion, and for instructing the engineer in those co-related sciences which must now be used for his advancement in life. There has thus arisen a strenuous, and in some cases a rather intemperate advocacy for an all-prevailing system of technical, apparently to the exclusion of every other kind of education.

From the very dawn of authentic history we find accounts of workers in timber or stone; in the baser metals, or gold; but these artisans guarded the secrets of their crafts with a jealous care, imparting them only to a limited number of apprentices.

Gradually, the formation of guilds took place, apparently as
ı to prevent a general knowledge of their trade, as to
·e its continuance. In thus guarding against what they
lered a too liberal extension of useful knowledge, they

have been succeeded by trades unions, so dear to the working-men of our times; and it seems not a little remarkable that the City of London Guilds, the inheritors of traditions of more than oligarchal exclusiveness, should be as anxious now to make trade secrets generally known, as their predecessors were concerned to retain them in the possession of a few.

And yet in reading history we do find scattered attempts to teach trades to outsiders, and one of the earliest seems to have been instituted by St. Basil the Great, Bishop of Cæsaræa. This most remarkable man was born about A.D. 329; and, during the reign of the Emperor Valens, he established a complete town in the suburbs of Cæsaræa, where there were workshops, in which "poor wayfarers," as they are quaintly called, might learn and practise various trades, under proper teachers.

Coming to later times, we find that in the midst of his experiments on the nature of heat, and numberless scientific researches, the celebrated Count Rumford found time to organise, and carry out successfully, a trade school for the very lowest classes. He describes an appalling condition of aggressive pauperism as prevailing in Bavaria; and it is most refreshing, in these days of so much sham philanthropy, to read the accounts of his arrangements for its removal. On the 1st of January, 1790, every beggar in Munich was arrested, and quartered in spacious buildings which had been prepared. Here they were kept clean, well fed, and taught various trades. They made uniforms for the army, and such other work as was adapted to their powers; and the care of the distinguished engineer provided even for their amusements. Instead of pauperism, there prevailed contentment, and the indolent and vicious became in some degree industrious and reformed.

Meanwhile, the poorer working classes were not overlooked: and the practical outcome of these most judicious arrangements of benevolent despotism, was the extinction of pauperism where it had previously reigned supreme.

Ancient workmen brought their handicrafts to great perfection; and the character of their masonry in Egypt, at Baalbec and throughout the East, and their productions in marble and bronze, attest their skill, and compel our admiration. The guilds carried on this work, without improving upon it; and during the middle ages, intelligence came to the aid of manual skill, and Cistercian monks brought architecture to a state of high perfection, and scattered their splendid cathedrals in numbers and in matchless beauty over many lands. Meanwhile chemistry and other sciences were greatly advanced through encouragement given by enlightened Mahomedan caliphs at

Bagdad and Cordova, and Arabian learning enriched Europe with an unequalled practical education.

The restless spirit of investigation pursued throughout Western Europe in secret by the alchemists, or in fear by the philosophers, may claim credit for advancing the progress of science: while the experimental inquiries of Lord Bacon, Robert Boyle, the Marquis of Worcester, and a host of men of humbler name, not only cleared the path, but also prepared the way for the truer study of science and for the modern engineer.

But of technical education as now understood, we find little trace until times within living memory.

Those who, like Archimedes of Syracuse, were the engineers of ancient history, esteemed little the practical applications of their genius, and preferred to deal with problems of pure geometry or abstract mathematics; sometimes wrapping up their conclusions in enigmas which only a later age has solved. So in modern times the mathematician and searcher into natural laws will too often disdain that kindly utilitarian spirit which would spend itself in doing most good to the greatest number.

Fashion too, and ignorance often combine in jealous sneers against that tithe of their own mercenary spirit which would use superior knowledge for the advancement of its possessor, and the general effect tends to maintain a standard as lofty in seeming as it is false in fact, that genius is a gem too precious to wear, and that science becomes degraded the moment it is turned to practical account.

This exalted standard has of late years happily yielded in some measure to common sense, but only after doing untold harm. It has not only impounded much of the richest treasure we possess, the inventive genius of our people, but has influenced many, who have all the pride of intellect and none of its power, to look with contempt on hard-working ignorance, whose name may indeed perish with his days, but whose works are of far more value than discussions upon life in four dimensions, and whose experience of natural laws teaches him more than all the philosophy of an Aristotle.

In defence of a purely classical education it has been fairly urged that it forms an excellent training in preparing the mind for further developments in its culture, but, as the classical school admits, a mathematical education ranks on equal terms. Surely, therefore, they cannot deny to an intimate acquaintance with modern science, the power of arriving at a similar end, with the additional advantage that it is usually of more interest and use through life than a cultivated talent for the composition of Latin verses.

There is, however, one point of view which forms an essential difference between the two schools, and is the best defence of classical training against that exaggerated spirit of utilitarianism which even goes so far as to suggest the destruction of all the gardens and parks of England for growing vegetables, and can see no beauty in a waterfall, but thinks only of the mills it might drive.

If the older system of education did not teach, and did not profess to teach, that abundance of undigested knowledge which the misleading standards of modern competitive examinations too often require, it did a better and a nobler thing, which the advocates of high-pressure education too often forget, or wilfully ignore. It never exhausted the immature undeveloped brain, but it taught the wisdom of ages past; it exercised the pupil in the application of such knowledge as he could easily acquire, and left considerable scope for his originality. Moreover, it laid down the firm foundation of all the intellectual culture of our nation, and produced a race of men of rare sagacity and high administrative talents—men competent to build up the splendid empire we inherit, and whom any country might well be proud to own among its sons.

Even from the restricted point of view as to what should constitute the best education for an engineer, considering that it may fall to his lot to rule more men than the armies of many a famous kingdom, and all unaided and alone grapple with difficulties, material and political, innumerable, none can deny that a study of the qualities displayed in Xenophon's 'Retreat of the Ten Thousand' will be to him of more value than a very intimate acquaintance with the differential calculus. And time spent in learning modern languages, enabling him to read the invaluable works of French and German engineers, is much better employed than the cultivation of such an amount of mere mechanical skill as would beat a fitter at his own trade.

Both the classical and the mechanical school of education have their good points; but no mere technical training can possibly place a man in such an exalted intellectual position as the classical system has done. There are men whose destiny it is to be the mechanical workers, and they must make technical education paramount, and intellectual culture can only be to them a refining luxury, to which their leisure may well be devoted: and other men whose natural gifts render them leaders rather than workers, can devote more time to brainwork and less to trade. In either case, technical knowledge is of great value, but its amount may well vary in their training.

The great end and aim of education should never be, as too often found, the cramming with mere knowledge, but rather

the cultivation of the power of applying knowledge, for that is true wisdom indeed.

These things are becoming better understood, and now that the cultivated classes have ceased to look upon the dirt and drudgery of mechanical toil as something degrading, and that scientific attainments are becoming fashionable, it is to be hoped that the blending of the older and the modern system which has been progressing in a tentative manner in our universities and great public schools, may grow and flourish, and that mechanical knowledge may more generally abound.

It might be interesting to pursue this aspect of the subject further, but time would fail, and your patience grow weary, and it will be more profitable to notice the course and progress of technical education during the past forty years, more particularly in its engineering aspect.

In history it is found that those nations most active and successful in war turn with greatest ardour to the pursuits of peace; and after the great European struggle which terminated with the exile of the first Napoleon, England, released from her absorbing care in those great events, commenced a development of her trade and resources which soon left her without a rival. The times were most auspicious. A young Queen sat on the throne of these kingdoms, whom Heaven in its goodness still preserves to reign over our favoured land; and with her Consort, a man of sound common sense and a deep student of political economy, her Majesty devoted untiring attention to everything that could encourage the development of all the resources of her wide dominions.

To second such enlightened views prevailing in the highest quarters, there was a people whose aggressive instincts had been diverted from the prosecution of a tremendous war to the pursuits of peace. Free from national anxieties, while honoured and respected throughout the world, it became a matter for no astonishment that trade of every kind increased with surprising rapidity, and the prosperity of our nation seemed to attain the zenith of its most ambitious hopes. The researches of scientific inquirers were abundantly rewarded by nature unfolding her choicest secrets to their ardent gaze. Literature and art also flourished in the wake of successful trade, and it seemed as if an era of peace and prosperity was dawning on the world.

No proof is now necessary that a very different condition of things prevails at the present time; for, instead of peace, we hear more of war; and instead of prosperity, all the music of the land is in the minor key. There is disquiet abroad, and discontent at home: and even our real riches and pros-

perity are made a cause of croaking and despondency by weak unmanly spirits among us, men immeasurably inferior to those who laid the foundations and reared the fabric of our country's greatness.

Following the example and profiting by the experience of England, other nations endeavoured, successfully, to enlarge the boundaries of their trade; not, however, in the fearless open-handed way in which England did not disdain to exhibit even her processes of manufacture, in the Great Exhibition of 1851, but in a mean and timid exclusiveness, characteristic of conscious weakness—afraid to let manufactures stand on their own merits with those of other countries; and taxing their own countrymen to prop up a system which could not stand without such adventitious aid.

In Germany, along with prohibitive tariffs, a somewhat different course was adopted, even when that great empire was divided into many small principalities, in uneasy antagonism among themselves. These Governments devised and carried out very thorough systems of education, and sent their journeymen apprentices to extend their travels beyond the confines of their own country. These young men came in great numbers to England, and being subsidised by their own Governments, they were able to work for less wages than our own people required, and being also docile and intelligent, they readily secured positions which gave them a thorough insight into the methods by which our trade was carried on. This experience enabled them, on returning home, or setting up on their own account, to reap great advantages from their English apprenticeship. Their education also gave them a better start than English youths of corresponding age; and the practical outcome of the competition we have had to meet from other countries has been, to draw particular attention to the education of those who are to be engaged in trades in our own country, compelling us to neglect no longer the warning voices of those who foresaw and endeavoured to supply a better system of technical education many years ago.

Indeed, so great has been the reaction, that many timid people nowadays are inconsiderately rushing to the somewhat absurd conclusion, that all our former plans by which England became so prosperous must have been wrong, and all we can do now is to admire and slavishly imitate a system which answers well enough in Germany, but is not necessarily adapted to a people like our own, of very different temperament. Rather ought we to choose good points out of the Continental systems, and engraft them upon the well-proved standard which educated our forefathers so wisely and so well. We should also remember

the born instinct for engineering pursuits which prevails amongst the English race, more than among any other on the globe; and take care to cultivate the originality, and guide the inventive genius of our people, rather than adopt a hard, unyielding, semi-military educational system, destructive of both.

The northern parts of England have for many generations been the chief seats of its manufacturing industries, and Lancashire is the county most keenly alive to the interests of trade; and in native talent probably the most intelligent of all. It has been well said that "where Lancashire leads to-day, England follows to-morrow," and in the matter of education this particular county has been in nowise behindhand.

The rapid progress in prosperity which marked the first period of the Victorian age from 1837 to 1851 affected Lancashire first of all, and led to the expression of a very general wish for a better system of education. The then leaders of society in that aristocratic county admirably fulfilled their duty; and following the old traditions that the Church has always been the great educator of the people, an imposing meeting was organised and held at Chester, under the presidency of the bishop of that great diocese, which then included Lancashire in its boundaries.

This meeting took place on the 25th January, 1839. It included the leading men of Cheshire and Lancashire, and its main object was most clearly set forth in a speech made by the late Earl of Derby, then Lord Stanley. He said that "between the higher and the lower classes there is a great gap to be filled up. There is a demand for an improving scientific education among the middle classes according to the march of science."

In consequence of this meeting, and following upon such important statements from one of the first classical scholars of his day, a deep interest was aroused in the two counties, and subscriptions flowed in abundantly to provide the means for a comprehensive scheme of education. The work was commenced at once, and my late father, the Rev. Arthur Rigg, was appointed to arrange and carry out its details.

The College at Chester was opened in the year 1842, and my father received its keys from the hands of the present Prime Minister, who in his green old age remains the last survivor of that band of eminent men who gave the great impetus to practical education more than forty years ago. The schools were continued and gradually developed "with such an ar[illegible] useful practical knowledge as may qualify the boys in a[illegible] degree for agricultural and commercial employ-

ments." In 1843 the Diocesan Report states that "many articles of furniture had been made by the boys in the intervals between their school hours," and the evidence of neighbouring manufacturers gave encouragement to the system of education, as they stated with considerable acumen, that if a knowledge of the combinations of machinery were taught in those districts, a very important lesson would be taken towards raising the moral and intellectual character of our artisans.

Many different trades were practised at the college, and again and again did Her Majesty's Inspectors testify that the knowledge gained in these workshops was more valuable than any other, and that (in 1850) they knew of no other place where such instruction could be gained.

In 1851, the tendency of the school towards the teaching of mechanical engineering became more pronounced: Mr. E. A. Davidson, the first science teacher educated by the Department of Science and Art, had taken charge of the instruction in geometrical drawing and orthographic projection, not only in Chester, but in the great works of the London and North Western Railway Company at Crewe. The workshops and laboratory were enlarged, and chemistry under the care of Professor Crookes (now F.R.S.), with other sciences, received their due share of attention. In 1862, a demand for engineers in India had arisen, and certificates of residence at the College, Chester, were "accepted by the Secretary of State for India from candidates for appointments, as if they had passed an equal time under a civil, mechanical, mining, or telegraph engineer," and large numbers of engineers now scattered over many lands received their education there.

When its founder retired in 1869, after the arduous labours of thirty years, this, the first engineering school in England, ceased to exist; and the only memento of his work now to be seen at Chester is an admirable marble medallion, which was erected last year in the college chapel by numbers of his former engineering pupils.

The novel and unique educational system thus carried on at Chester caused the school to be visited by numerous Englishmen and foreigners interested in the subject. It thus served as a pattern and encouragement for others, and things have now reached such a pass, that now there is hardly a school for boys or girls of the smallest pretensions that does not teach science of some sort.

Numerous schools now exist in London and in the provinces, where admirable instruction is given in the principles and practice of engineering, both civil and mechanical. At King's College in the Strand, University College in Gower Street,

at the Crystal Palace, and in the Technical Schools in the City of London, there are classes devoted to these subjects; while in the provinces at Owens College, Manchester, the Hartley Institute, Southampton, and the Corporation College at Nottingham, and other places, technical education is carried out: so that the younger generation of Englishmen cannot fall short of those advantages which may possibly have been one of the reasons that have enabled foreigners to run them so close. For an exclusively engineering education the chief place must be assigned to the College at Cooper's Hill, now opened for the education of all engineers, not specially of those destined for India.

With schools so numerous and so good, some might be disposed to think that the older system of apprenticeship to engineers has become unnecessary: but no error could be more damaging to its victim; for do what you will, a school can never supply the experience necessary for practical life. Where indeed is such experience to come from? Not from the pupils or students, for they are often ignorant of the art of learning! Neither are books fit instructors for the many-sided requirements of ordinary life; and, however clever the professors, it is physically impossible for one among many to teach them as much as they will learn when they occupy a corresponding position scattered and isolated among others. The conclusion we are forced to come to is, that no final training can ever be so good as carrying out works under the guidance of an engineer engaged in the ordinary affairs of his profession. A school is a world in miniature, and so far as a child resembles a man, the comparison is just; but it must not be carried further, and the best that any school can do is thoroughly to ground its pupils in general principles, and give them an insight into the best methods of their application.

An engineer has to administer the perfect laws of nature, and although these are described in text-books as unchanging and unchangeable, yet so hard and fast a condition of things is very far removed from what actually prevails. All these laws are subject to modification by external influences, and no mathematician can calculate, nor can any array of figures convey to the mind, their infinite variety.

If, for example, we take a law so definite and absolute in its dominion as the attraction of gravity, a law which affects the limitless boundaries of eternal space, equally with the irresistible attraction, revealed by no microscope, which holds together what we call the atoms of solids, we soon find that there are other laws equally universal, which may override the attractions of gravity.

Centrifugal force, heat, and chemical affinity alike limit its extent, and a clear insight into all natural laws reveals how easy it is for us to regulate material things exactly as our varying needs require, without in the least denying their potency or curtailing their universal sway.

The architect and civil engineer need only consider the statical properties of immovable bodies, while the studies of a mechanical engineer must include the whole range of their dynamical relationships. These greatly modify his methods and practice, and may indeed be regarded as placing him on a higher standing from a scientific point of view.

Then again, intruding into the domain of matter and motion, chemistry enters more largely than formerly into the education of an engineer, and there is no other science to which he is more deeply indebted.

If we consider the few elementary substances with which an engineer has to deal, they are found beyond all others endowed with the most unexpected and even contradictory qualities. These elements are four in number—oxygen, hydrogen, carbon, and iron; and without trespassing into pure chemistry, or wearying your patience with what is after all an adjunct of engineering, I think we may briefly consider what are some aspects of those substances so important to an engineer, and what some of their peculiarities.

Oxygen, the main support of life, while also one cause of its decay and ultimate destruction, combines with every other substance, and may be called the haven of rest, or indeed the "Nirvana" of all material things. The comparatively small amount free in our atmosphere, is the residue from those imposing conflagrations which ushered in the present order of things, together with what has been rescued from its combinations by the strangely mysterious power of sunlight.

With nitrogen, itself the most inert of gases, and oddly enough, the essential ingredient of explosive compounds, oxygen forms the most corrosive of acids, while in combination with hydrogen it is the purest and most useful substance we know. In its higher allotropic form of ozone, chemistry itself seems baffled in assigning limits to its protean character.

In water we have a marvellous and most unlooked-for development of powers and qualities of which not a trace can be found in either of the gases of which it is composed. A liquid unique amongst all others, possessing the highest known specific heat, and familiar to us in three conditions, it becomes the most convenient means for transmitting heat and utilising the chemical energies taken from the atmosphere countless ages

ago by the sun, and locked up for our present use in the most perfect of "storage batteries."

If we notice, in passing, the combinations of hydrogen and carbon, it is only to remark how the engineer who is concerned with gas-works must devote great care and attention to their study, and how of late years his colleague the chemist has positively made the bye-products of gas-making a source of greater profit than the hydro-carbons with which our streets and dwellings are illuminated at night.

Carbon is perhaps, without any exception whatever, the most wonderful substance of which we possess any knowledge. At once the most permanent of all things, and the one which unchanged endures the most intense heat we can produce—that of the electric arc—this substance combines so easily with oxygen as to be readily burnt in our fires, and thus to it we owe most of what renders life supportable. And yet its affinities are so admirably adjusted, that during the combination of a hydro-carbon with oxygen, as may be readily seen in an ordinary candle flame, the hydrogen is first consumed, and raises the carbon to such a temperature that its solid unchanged particles illuminate the feeble glow of the hydrogen flames before they themselves are changed into an invisible harmless gas.

In blast furnaces this singular adjustment in the affinity of carbon for oxygen at different temperatures is made to play an important part. Those metallic oxides which are the chief ores of iron are reduced by the superior attraction which carbon possesses for oxygen at high temperatures; and if the pure metal so extracted be again exposed to atmospheric influences, we witness the curious phenomenon of its recombination with oxygen at ordinary temperatures, while carbon would remain for ever unchanging at its side.

This variation, at different temperatures, of the affinities for oxygen by carbon and iron amounts to a complete reversal of an ascertained law. A philosopher residing in a planet where high temperatures were unknown, might most justly assert that oxygen possessed a greater affinity for iron than for carbon; whereas an inhabitant of the sun might on equally good grounds come to exactly the opposite conclusion. Thus this law, like many others, is governed by the conditions under which it is exercised, and it forms one of many illustrations, how easy it is to bend the inflexible laws of Nature to suit our endlessly var- uirements.

Carb- s a greater number of separate compounds than a -ment, and even these compounds sometimes behav- ry substances, and combine amongst them-

selves. The conditions of mere mixture, and as carbide of iron, under which this element changes that metal into steel and cast iron, endowing it with new peculiarities, are at the present time the subject of an elaborate investigation by some of our leading metallurgical chemists, and the final result of their labours will be awaited with deep interest by engineers.

Familiar qualities of all substances gradually disappear as they change from a solid to a gaseous condition. The hardness and brittleness of cast iron finds no place in its liquid state, nor can the properties of any liquid be traced in its gas. Thus we only know the properties of bodies such as are displayed in the narrow compass of temperatures which we can observe, and cannot tell anything of their mutual relations under different conditions of temperature, density, and of perhaps unexpected allotropic changes in their nature.

Iron is the most important element with which engineers have to do; indeed, it may be said that they could not exist without it. This metal is more plentifully distributed than any other: easily reduced from ores, and possessing very different qualifications according to the proportions of carbon or other metals with which it is combined. In common with platinum, wrought iron has the rare quality of welding, by which its atoms at a white heat seem to be removed sufficiently far apart as to be within the sphere of attraction of another bar similarly heated and driven into close mechanical contact. But it is not alone in these qualities that iron is so remarkable a metal. Its peculiarly electrical and magnetic properties have within the last few years rather distracted attention from its other natural gifts. The investigations to which iron has rendered such signal service have tended more than anything else to place this youngest born of sciences in the position which now it occupies.

Although the effect of an electrical current in producing magnetism was first discovered by the late Professor Faraday in the year 1831, it was not until the year 1834 that this distinguished philosopher invented and showed at the Royal Institution an early form of dynamo-electrical machine; and, after resting for many years, and being the subject of many experiments, this machine has been taken up by a class of men of very different character to its original inventor, and it is only quite recently that engineers have had anything to do with it. Not like the older sciences, a slow growth of centuries, nor like engineering, the work of an entire generation, this precocious infant of days seems to have sprung into existence all at once, and everybody is expected to accept as proved the

crude theories and unfounded assumptions of those who claim to be the sole depositaries of the secrets of a new science.

To the general public, ignorant of a new and uncouth nomenclature, and disconcerted by an array of mathematical symbols, which, if they knew the truth, not unfrequently resemble sheep walks on a barren moor, that start from nothing and lead nobody knows where, some of the electrical companies have made too hopeful promises, and financial disaster has proved an inevitable result. Indeed, we may see that the elementary principles of mechanical engineering have been entirely unknown by them, and that many thousands of pounds have been wasted in the construction of ill-designed machines which were little else than dangerous experiments for ascertaining the simple laws of centrifugal force, or the correct proportions of pulleys and bearings for transmission of power at high speeds. We used also continually to hear of irregular driving and engines breaking down; and though these evils might arise through mistaken cheapness, or not knowing the actual power transmitted in driving dynamo-electrical machines, yet, as the indicator was invented by Watt, and is now in universal use, such ignorance is wholly inexcusable, and no educated engineer could possibly make such a mistake.

All these proceedings form a good illustration of the need for some standard of qualification which shall enable the public to place confidence in a man's claim to rank as an engineer; and there is, unfortunately, no such security of any kind in this country. Besides, many people possessing the merest smattering of engineering, who would resent the suggestion that their own simple arrangements might be improved, will yet consider themselves perfectly competent to design or arrange a complicated mechanical combination, or discuss details which can only be mastered by much study and experience. In a new departure like modern electrical science, it was only natural that experiments were necessary, and failures to be anticipated, and it is not to such that we allude; but that it should be implied that every educated engineer does not know the proper proportions of pulleys and belts to transmit a given power, nor how to construct an engine that shall not break down, is to place a most unmerited slur upon the profession.

In the construction of their machinery, the electricians have by this time blundered into more reasonable proportions; but they cannot be surprised that their want of knowledge in these matters, so generally known, should hardly form their best creden[illegible]r making statements upon the details of a science the [illegible]erious and extraordinary ever brought under the dom[illegible]an.

The practical details of electrical work are quite distinct from the true engineering involved in construction of engines and machinery, and in it electricians may fairly claim a position of their own; and it is only in continuation of previous remarks upon the unique properties of iron, that I would venture to make a short excursion into their special province.

Whether neutralised electricity or magnetism exists in all substances or not, remains still to be proved; but certain it is that the earth and sun, and probably all the other planets, are powerfully magnetic, each as a whole. It is principally through the properties of iron, that we are able to bring magnetism to practical use: and if we study Professor Hughes's most interesting experiments on the polarisation of its molecules under the influence of electrical currents, we see how, as by the action of wind on a field of corn, the magnetic pole of each molecule is turned in the same direction, and a maximum effect is reached. When, with pure iron, the exciting cause is withdrawn, the molecules again neutralise each other, and no external magnetism is perceived. But the addition of carbon, as in cast iron or steel, necessitates increased electrical force to rotate the molecules, and at the same time prevents their ready return. It is this property of carbon which gives us permanent magnets; and although the outlines of this theory are not new, yet Professor Hughes's experiments promise to throw more light upon the subject of magnetism, and collaterally upon the internal constitution of matter, and we may await their development with increasing interest.

If magnetism is thus shown to be the polarisation of molecules of iron, what can electricity be, with which it is so intimately associated? It is an influence subject to none of the laws of matter, and has been ascribed to that mysterious ether which enters into the innermost recesses of all material things, like light through transparent glass, and at the same time seems only bounded by the confines of infinity. This appears to be the vehicle by which the light of stars is transmitted to our eyes, and may be the medium through which gravity acts, though not subject to its sway. It is an influence for the appreciation of which another sense would be required beyond the five we now possess; for its presence cannot be detected by most refined analysis. Like ozone, which hints at a fourth condition of matter, this mysterious essence limits no bounds to the potentialities of a scientific imagination. Indeed, may itself not be the subject of a neutralised state of quiescence like iron; or may there possibly be a polarisation of its own inner nature which we call electricity? None can dispute its myste-

rious character, or chain its awful potency. It knows no limits of infinity at either end of the scale in magnitude or minuteness, and seems as intangible and unknown as the very nature of life itself.

Such matters as these naturally give rise to the reflection that if we are able to learn so little of the nature of the materials in daily use, while they are ready to answer judiciously directed experimental enquiry—if we cannot ascertain more than the existence of an ether which pervades and seems to govern all things—how can science be reproached for its failures and for its superficial knowledge? Rather should we feel grateful to its exponents for their courageous attempts to pierce the surrounding gloom, and forgive their pardonable dogmatism in favour of a new theory. If any new theory serves no other purpose than a temporary beacon to guide through the dark recesses of the unknown; and if such reasoning by analogy aids in searching out the unity of working of a single mind, it is no reproach to a theorist that the self-sufficient "practical man" cannot climb with him to the top of Nebo, and see the promised land; nor that his theory may be shattered in the dust for another of wider scope and more general application. Thus we know and slowly learn that knowledge itself is not exempt from universal development, and is under the despotic sway of that inexorable law of nature: "the survival of the fittest."

It is time, and more than time, that this long address should come to an end, and I trust that it has not wearied your patience altogether. It has been my endeavour to show forth something of the many-sided aspects of modern mechanical engineering: of its all-embracing character and its exalted destiny. It is becoming a science of the very highest rank in intrinsic worth as in practical utility, and one that is deserving of the most attentive study.

But most of all I would protest against the too common idea that abundance of knowledge is the only thing to teach or learn. The reading of many books is only to store the mind with a miscellaneous collection, without order or classification. But it is the province of true wisdom to teach the right use of knowledge in the application of this store to the best advantage; and such wisdom is most to be desired, and worthiest of all things for our gain.

March 3rd, 1884.

ARTHUR RIGG, PRESIDENT, IN THE CHAIR.

THE DEFECTS OF STEAM BOILERS AND THEIR REMEDY.

BY A. C. ENGERT.

STEAM boilers are used as a medium to convey heat or the accumulated force produced thereby to an engine for the purpose of moving machinery to do certain work. The heat rises from the burning fuel within the boiler-furnace, and penetrates the metal to heat the water in the boiler to 212° F. so as to form steam; but before its actual formation 966° F. has to be absorbed. Steam has no power to move a piston at such a low temperature, therefore more heat is required to produce the necessary force, and the higher the degree of heat contained in the water and steam, the more pressure will the steam exert on the piston when allowed to enter the cylinder. It is of the utmost importance to have perfect combustion, so that the whole of the heat may enter the water in the boiler. For this purpose various shapes and forms of boilers have been invented, but the Cornish and Lancashire types are found the most convenient for general purposes. Now 1 lb. of good coal is capable of evaporating 15 lb. of water, but these boilers are only capable of evaporating one-third or at the best one-half of the quantity of water they should do in proportion to the fuel consumed (which is far too small a proportion), owing to the flame and heat wave rushing through the flues too quickly for the heat to thoroughly penetrate the metal. Improvements have, therefore, been introduced, such as Galloway and other cross tubes, in the Cornish and Lancashire boilers, which have proved to be very advantageous in saving fuel, so long as they are kept quite clean. But even with these improvements the average evaporation is not much more than half that which theory shows it should be, owing to incrustation. This evil of incrustation, together with unequal expansion and contraction, and the corrosion in boilers, are hindrances which ought to be removed.

In the author's opinion several of these evils are due to the

construction of Cornish and Lancashire boilers. For instance, the ashpit, which is used to convey air to the burning fuel in the furnace, allows cold air to enter, which keeps the bottom part of the boiler cool, and stays the circulation of the water within. If warm water even be fed into the boiler a part of the heat is again lost from the above cause, and the heat supplied to the bottom of the boiler is also partly lost, so that the lower part of the boiler is almost entirely useless for forming steam. Another trouble arising out of this evil is the unequal expansion of some of the plates. The top part of the boiler being hot and the bottom cool, causes great strain at various seams, as the expansion and contraction are continually affected by the varied draught or temperature, often loosening rivets and causing leakage, and endangering life and property. Another bad feature in this description of boiler is that the bottom of the flue and the shell being very close together, it is hardly possible to clean those parts properly. This is of great importance, as on that particular part the most settlement takes place, the water being there almost stationary.

Among the general evils to which boilers are subject, incrustation is one of the principal, because all waters contain certain impurities which settle in the boiler, as the heat cannot dissolve nor drive them off with the steam. These settlements remain generally where the steam is formed, and get baked into a hard scale on the plates, but mostly on the crown of the flues and conical tubes. As this scale is a non-conductor of heat, it requires 15 per cent. more coal when the scale is only one-sixteenth of an inch thick; and when it is a quarter of an inch thick, 60 per cent. more coal is required. It is not only the coal which is thereby wasted, but the water is kept away from the boiler plates, which become overheated, and eventually have holes burnt in them. To prevent incrustation, various solutions and many other remedies have been tried. The author desires to draw attention to the remedy which the chairman of the Manchester Steam Users' Association has recommended. This consists in putting 3 lb. of soda ash every day in the feed-water of a 50-horsepower boiler, and to frequently blow off. Besides this, he recommends the Porter-Clark process, which consists in putting lime-water into the feed-water, which throws down all the carbonates, and the water is then filtered and ready to be pumped into the boiler. Still, this process does not touch the sulphates.

Another trouble with boilers is the formation of smoke and the loss of unconsumed gases. In reference to this, the author had the honour, in June 1881, to read a paper before this Society "On the Prevention of Smoke"; he also sent a letter

to the editor of *Iron* (which was published in that paper for December 21, 1883), entitled "The Cause of Smoke," of which the public has never been informed. A few points therein may, perhaps, be re-stated here, as some of the younger members of the profession may have thought the subject too unimportant to be inquired into. The author wrote as follows:—"When fresh coals are placed on the fire in an open firegrate, smoke rises directly. The cause of this smoke is not very far to seek, as it will be easily understood that before the fresh coals were put upon the fire within the grate, the glowing coals radiated their heat and warmed the air above, and thereby enabled the rising gases at once to combine with the warmed air to produce combustion, but since the fresh coals are placed upon the fire these coals absorb the heat, and the air above remains cold. The fact is that these volatile rising gases cannot combine with the cold air for combustion, still a combination does take place in the following way:—The cold air in the act of combination absorbs a part of the warmth of the rising gases, which they cannot spare, and therefore they (the gases) must condense, so much so that small particles are formed, which aggregate, and are called smoke, and when collected form soot, but so long as these particles or gases are floating they cannot burn or produce combustion. Of course the invisible hydrogen gas rising from the coals with the smoke would burn easily enough, but it must first be lit before it can burn."

The above sentences only refer to open firegrates; in furnaces, smoke and waste of gases may be caused by too small a quantity of air, so that there is not enough oxygen to satisfy the rising gases, or there may be too much air, which, whilst passing through the furnace, absorbs heat and thereby impoverishes the combustion.

In the paper on the prevention of smoke, read before this Society, the author expressed a strong opinion that smoke once formed could not be consumed, and gave his reason, and he finds the following in a work frequently consulted by boiler-makers:—"We see, then, how palpably erroneous is the idea that smoke once formed can be consumed in the same furnace in which it is generated, and how irreconcilable is such a result with the operation of nature, and it is only the cooling down of carbon which produces smoke." Here then, again, smoke is attributed to the cooling down of the gases, and the author thinks the cause not only of the loss of a few grains of carbon, and the other invisible gases (which amount often to a high percentage), which go out with the smoke, but also the trouble and unhealthiness produced by smoke, cannot be referred to too often. It is, of course, well understood that cold air must be

prevented entering the furnace, and for this purpose mechanical stokers have been invented, not only to prevent the formation of smoke, but to save fuel. Experience, however, has taught us otherwise.

Referring to the Manchester Smoke Abatement Exhibition, *Engineering*, April 28, 1882, after stating what the various mechanical stokers profess to do, observes that very many mechanical stokers are thrown out of use after a time, and the old hand-firing again resorted to. It is also remarked that though the machines are pleasing and satisfactory at first, the main result in the long run is that the mechanism is troublesome, wasteful, and costly. Later on it is stated that "it would be interesting to know the actual number that has been fitted to boilers during the past five years, and in how many cases they are still at work."

In the Report of the Manchester Steam Users' Association, April 24, 1883, is the following:—"The question of smoke prevention, and the relative merits of mechanical and hand-firing, has been carefully considered by the Association, and the conclusion arrived at was that as regards economy, the two modes of firing gave practically the same result; as many as fifty-five mechanical stokers had been removed from boilers under inspection. To prevent smoke by hand-firing, nothing out of common was wanted, but only a reasonably fair draught, a reasonably fair boiler, regular firing, and the admission of a little air above the firebars, to secure the combustion of the gases."

In the Report of the Jurors' Committee of the Smoke Abatement Exhibition, it is stated on page 25, as to mechanical stokers, that "most of them require occasional assistance by hand," thus showing that they are still open to further improvement. In the above Report it is stated, on page 27 (Firebars, fire-bridges, furnace-doors, &c.), that "the Committee are of opinion that any assistance by which air is introduced with the view to complete the combustion either of gaseous or of solid fuel is objectionable, and is not likely to lead to the most economical results."

These statements of high authorities support the author's opinion that smoke cannot be burned in the same furnace where it has been formed, and much less is any furnace-door able to produce complete combustion of the fuel burning within the furnace. In fact, entire combustion is almost beyond the means of man, in an ordinary furnace. Still, improvements have been made, by introducing warm air to combine better with the rising gases of the burning fuel. But this is no easy matter, considering that 150 cubic feet, or

22 lb., of air are required for each pound of coal burnt; and it is a fact that the carbon requires great heat before it can be burnt, and, further, that all solid fuel formed into gases and compressed gases while expanding absorb a large quantity of heat before they can burn.

On this subject *Engineering* for December 2, 1881, says:—"Total combustion means, not merely the rendering the products of combustion invisible, it means the conversion of the carbonic oxide produced into carbonic acid." Another author says:—"The carbon burning in the flame has not completed its combustion, and it is only the high temperature of hydrogen burning which will enable the carbon to combine more readily with the oxygen in the air." It is only the clear white flame which will show that combustion is in its proper condition and everything is well heated.

To prove that the carbon in the flame is only completing its combustion may be seen by the flame of a gas jet or of a candle, which gives a very white light, as, for instance, the Siemens gas lamp. But if a little air be allowed to blow in from the bottom, then the white light will blaze out in a long dark red flame, and give little light, but plenty of smoke and soot. Again, if a plate be held over a gas or a candle flame, carbon, i. e. soot, will settle on it, and the deposit is increased when the plate is held lower in the flame, in fact the burning of carbon in a flame is only one of the stages of combustion, and when combustion is interrupted or incomplete it produces smoke, which is increased, while the invisible steam formed by the hydrogen will condense and cling to the dust of the carbon. This can be proved by the flame in a furnace; the lowest part of the flame, where the carbon has just combined with the oxygen, is generally much darker, even when the top is quite white, and is giving the greatest heat of some 2000° F., and when the flame is entering the tubes of a marine boiler, the bottom tubes are getting choked with soot, while the top flues, owing to the white flame, remain clean, and produce the heat required for forcing steam.

When fresh coals are placed in the furnace, the stoker generally leaves a small quantity of fire on the dead-plate, upon which he places his green coal, and then closes the furnace-door. This method the author thinks entirely wrong, as the heat from the fire underneath drives out the gases from the green coal in such rapid succession, that it is almost impossible for combustion to take place, even if the materials were ready for combustion. Such, however, not being the case, most of these valuable gases escape and are unproductive. If the fire on the dead-plate were raked to the front near the door,

and the green coal placed on the dead-plate between the two fires, the small quantity of air entering the furnace-door when shut would be warmed, and would ignite the rising gases from the green coal. At any rate, the first gas rising from the green coal is generally hydrogen, and as this gas has a greater affinity for oxygen than for carbon, it takes the first supply to form invisible steam and produce the greatest amount of heat whilst burning, thereby preparing all the other gases for proper combustion.

To carry out this plan, the dead-plate might be made a little larger so as to receive more coal at longer intervals, but the carbon gas at first very seldom combines with more than eight volumes of oxygen, forming carbonic oxide, as the carbon gases have to be formed from the solid carbon, and only afterwards while burning combine with eight more volumes of oxygen to form acid. Of course, if the draught is slow, which is always better for proper combustion, and if there be more carbon gas within the flame, then another six volumes of carbon gas is absorbed, and oxide is formed again. This, then, would be something like proper combustion, and would produce the heat required. But where is the quantity of warmed air to come from in the Cornish and Lancashire boilers? As the jurors state, in their opinion "air ought not to be allowed to enter above the firebars." Some very elaborate furnaces with hot-air chambers have been built, but they are so expensive, and occupy so much space, that they are rarely employed. The atmosphere passing through the firebars and incandescent fire above, is not at all times sufficient for complete combustion, especially when the draught is weak; and as it has been shown that burning carbon is taken up by another eight volumes of oxygen, it is almost necessary to supply warm air above the firebars if the proper combustion of all the gases is to take place. The densest smoke is formed when stoking is commenced, or the partly burned coals in front are pushed backwards on the firebars. The coals now disturbed having been warmed and their pores opened, the previously confined gases rise in a mass, but meeting the cold air entering partly from the open firedoor and partly through the firebars, the gases condense and form smoke. To save this great loss of gases, and to prevent the formation of smoke, the damper ought to be nearly closed before the furnace-doors are opened. If this plan is not adhered to, the owner of the boiler will not only lose all the gases as stated, but in addition some 8 lb. to 10 lb. of coals, to make good the ch has entered the furnace and flues by the door.

Priming is ar common to boilers in general, and

although a very important matter, the author has been unable to find any reference to this subject even in the most important works on boilers. He, however, found in a paper read before this Society by Mr. Wm. Major, on April 9, 1877, the following:—"It is certainly humiliating for the profession to be obliged to admit that one hundred years after the introduction of the steam engine, they are still unable to subdue an evil so generally experienced as priming of steam boilers; yet such is the case, as proved by the *Serapis*." Further on it is stated, that tallow and other remedies have been tried with various results, some doing harm to the boiler-plates. It is, however, stated that petroleum, mixed with the feed-water according to Mr. Major's invention, proved perfectly successful, as shown by a letter from Copenhagen, about one gallon of petroleum being used per day in a 30-horsepower boiler. Beyond these statements very little is said about the cause and remedies of priming.

The author will now give his opinion and experience of priming in boilers. The warming up and starting of an engine in the morning requires a large amount of steam, as considerable condensation takes place at first, more especially in the winter. The great quantity of steam taken from the boiler in so short a period very often reduces the pressure of steam within the boiler some 25 to 40 per cent., and considering that the flues by that time are not very hot, and are not able to form steam, the whole formation of the steam required is thrown on one small plate or space just over the bridge of the Cornish or Lancashire boiler, in fact, this small part of the boiler has produced or formed the whole of the steam and pressure within the boiler, and therefore this part must be very hot, and the water close to it absorbs more heat for expansion to form steam, and is consequently lighter than the water just above it, and possesses greater accumulated heat for the moment than the steam bubbles already formed. The heated water, with the lighter steam bubbles, are therefore thrown up together, when the pressure from above is suddenly removed, and forced into the engine.

The working of a vertical boiler may serve to make this case clearer. The steam formed having to force its way up through a column of water from 1½ to 3 feet deep, of course produces some pressure, and the water on the top being cooler than that at the bottom, the single bubbles of steam are hardly able to force their way up, and a combined effort is required (which may be said to cause a convulsion within the column of water) for the steam to raise itself, and then the superheated water is thrown up with the steam. This so-called priming in the

vertical boiler is not seen in the water-gauge so long as the water is kept low, say about 3 inches in the glass, but if the water be pumped as high as say 5 or 6 inches, then the water thrown up with the steam shows itself in the glass from the top. This, then, proves that the water forced up with steam will by gravity fall back in about a space of 3 or 4 inches from above the water-line, and the steam so cleared will show very little priming. Pure water will no doubt prevent priming to a great extent, but where boilers are forced or the water stands too high in the boiler, then the convulsion will be stronger, and a higher space for the steam to clear itself will be required. These facts prove two things—firstly, that in most instances the heat is applied on too small a space, and thereby harm is done to the boiler; and, secondly, that the steam space above the water-line is insufficient. These two conditions not only destroy or do harm to many boilers and engines, but cause a loss of fuel and power. The best means for the prevention of priming will be explained later on.

The author thinks too little attention has been given by steam users in general to the air and gases with acids contained in the feed-water, as these acids not only corrode the boiler-plates, and produce galvanic action with the grease returning to the boiler with the condensed steam, but the gases accumulating in the boiler amount to something more than is generally supposed. All water contains at least 2 to 3 per cent. of absorbed air and gases; such air and gases, being continually pumped into the boiler, accumulate. It is known that all gases are by gravity heavier than steam, the steam being on the top in the boiler, is allowed to pass from thence to the engine, the gases remaining behind, and, as carbonic acid gas is the heaviest gas, it takes the lowest place.

Now a 50-horsepower boiler will use about 3000 gallons of water per day. Then there would be as much as 14½ cubic feet of various gases accumulated, and in a week, some 80 cubic feet. These gases can only be expelled from the boiler by frequent blowing off; and if this be neglected, the gases and acids accumulate to a very great extent; and the author is of opinion that if an explosion then took place, it would be much more violent on account of the accumulated gases. They increase in volume as 1 in 490 at every degree F., so that at 50 lb. pressure the accumulated volume of gases will nearly be doubled, and thereby give an after-pressure to the steam to blow the boiler to atoms.

Manchester Steam Users' Association and other autho-
ave expressed the opinion that there must be something
steam pressure in many explosions. The return side

and bottom flues of a boiler ought to be rounded off, as all corners prevent the proper flow of the air and heat-waves. A few bricks sticking out in the flues from the brick walls will throw the heat-wave towards the boiler.

The author having stated some of the existing faults and their remedies in Cornish and Lancashire boilers, will now explain the improvements made in a boiler designed by himself, which has undergone some very severe trials. The object of the author was principally to do away with the ashpit; to prevent, if possible, incrustation; to extract from the water all gases; to prevent unequal expansion; to produce dry steam, and, by having better combustion, to prevent smoke. To obtain these results, he designed and had manufactured the boiler shown in the engravings, where Fig. 1 is a transverse section, and Fig. 2 a longitudinal section. In this boiler two flat flues are placed one above the other in a cylindrical shell 16 feet 6 inches long by 7 feet diameter, of which the top flue is 4 feet 8 inches wide by 10 inches high, and the other 4 feet 6 inches wide by 10 inches high, the top one being stayed with twenty-four, and the bottom one with thirty-three 3½-inch vertical tubes screwed into the flue-plates and expanded. These two flues have one-fifth more room for water and steam than the two flues of a Lancashire boiler, the top flue having its front bottom plate slanting downwards to make room for the firebars and furnace. On the front of the boiler a cast-iron box is fixed, with the bottom open, having doors in front with slots and slides, and perforated baffle-plates. The firebars rest in front on a strong bar within the cast-iron box, and the back ends of the firebars rest on the top end of the slanting flue. The front ends of the firebars are turned up to prevent the fire falling out. A sheet-iron curtain hangs down, so that when the doors are opened the fire is not exposed; when firing is required, the curtain is raised, and the damper is nearly closed automatically, so as to prevent cold air rushing into the furnace and flues. On the back end of the boiler there is a closed tank, 4 feet 8 inches wide, extreme height 4 feet, and 1 foot 10 inches deep. The water is supplied by gravity from a higher cistern, and a 2-inch pipe is carried from the tank through the roof, for the purpose of discharging the air and acids. The firebars sloping towards the front were designed so that the air should not merely pass through the firebars and then rise to the boiler-plate, but that the burning gases drawn towards the flue should continually meet and amalgamate with the other gases and meet the warm air coming through the slots in the front doors, so as to produce carbonic acid close under the boiler-plates, and to evolve the greatest heat at the proper places.

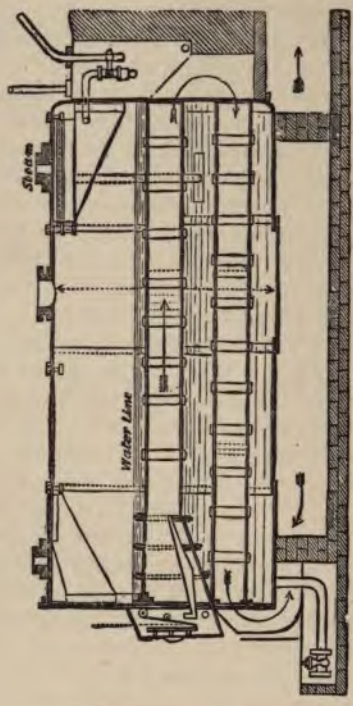


FIG. 2.

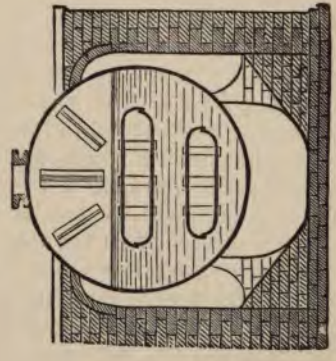


FIG. 1.

The flame or heat-waves in their passage are retarded by the vertical tubes, which they embrace, and thereby spread the heat to the top and bottom plates; the other part of the flame rushing by will do the same duty by the next tube, and so on to the end of the top flue. Here the heat-wave is obstructed by a water-tank for boiling the water contained within it, and the same process goes on at the bottom flue. Passing out at the front, the heat is led to the right side flue, returning under the bottom of the boiler, and passing to the left side towards the damper and shaft. The water does not remain long enough in the tank to be sufficiently boiled to throw down the carbonates and sulphates of lime, and therefore a live-steam pipe is carried from the boiler into the tank, and enters a large 4-inch pipe, which, with 50 lb. pressure, will produce close to the pipe some 240° to 250° Fahr., which heat will throw down the carbonates and sulphates (which are drawn off below), and send the acids and air out of the tank. The feed-water supply is taken from the hottest place over the pipe and is pumped into the boiler, and as this water is almost pure, and at the boiling-point, it produces no settlement or scale within the boiler.

The steam supplied to the water-tank is then led by a pipe to the front, under the firebars, and allowed to escape in small jets for the purpose of warming the air under the grate. The steam passing through the incandescent fire will be partly dissolved into its two elements, oxygen and hydrogen, of which the oxygen will at first fly to the carbon, and the hydrogen will burn above with fresh oxygen again to invisible steam, which if collected would produce nearly a $\frac{1}{2}$ ton weight of water from a ton of coals, if proper combustion had taken place. The steam jets are principally for the purpose of obviating the necessity of a very strong draught. The damper being half closed to prevent the heat from entering the chimney, the quantity of steam supplied under the front bars is very small, for if a large supply of steam was used it would become superheated by the burning fuel, and rise by its gravity close under the boiler-plate, thereby preventing the heat from penetrating the metal, and proving that steam ought never to be employed above the firebars. The vertical tubes after one year and a quarter of work are found to be as clean as if they had only just been put in. The circulation is so rapid that there is no settlement on the bottom of the boiler. On the top flue only there is found a small quantity of sediment, which is easily removed by a water-hose, and the scum on the sides of the boiler can be easily brushed off. Another advantage is that the bottom of the flues produce almost as much steam as the top, because no

stationary steam globules are permitted to accumulate, in consequence of the rapid circulation through the vertical tubes, in which no settlement or scale can attach itself. However large the flat tubes are made, it is impossible for them to collapse, on account of these vertical tubes or stays. The total heating surface is 577·7 square feet, and the grate surface 13 square feet. There are, therefore, 44·4 square feet of heating surface per square foot of grate surface. The author finds that, by a slow combustion and a gentle draught, more heat is evolved and penetrates the metal, and that there foremore water is evaporated per lb. of coal.

There being no ashpit in this boiler, and the boiler being entirely bricked in, no unequal expansion can possibly take place. As no cold air is allowed to enter the furnace, no smoke can arise except at the moment the curtain is let down and the damper raised; but this vapour is so trifling that it is hardly worth mentioning. A boiler on this principle was laid down by the author for driving the machinery at his works in Three Mills Lane, Bromley-by-Bow, in December 1882, and has been tested by several independent engineers, amongst others by Mr. W. H. Maw and Mr. D. K. Clark. With this boiler there is no priming, dry steam being produced (as stated in *Engineering* for September 14, 1883), tests having proved it to be thoroughly dry. Mr. D. K. Clark, in his report, states :— "I tested the steam produced each day for dryness; it proved to be dry and free from priming water." The explanation of the dryness of the steam is very simple, and is due to the large flat surface of water in the boiler, of about some 112 square feet area, which for the most part is only 3 inches deep, and having a heated flue-plate of some 80 square feet below, and twenty-four vertical tubes, which with a volcanic action continually send up the steam formed within them, and that from below, caused by widely distributed heat-waves. Then there is such a rapid circulation that no pressure arises from a volume of water, and there is no force or convulsion present to form steam bubbles. With shallow water and well-distributed heat, priming is therefore prevented.

Thus the principal defects of boilers have been remedied by this new design. There is very little waste or ashes, no clinkers in general, and only a few cinders, which may be used again. The stoking is very simple, as the coals are placed almost in front, the bars are short, and slanting to the front. In *Iron* for October 5, 1883, it is stated by the editor that this boiler has realised the highest efficiency on record, and that it marks a new phase in boiler construction. In the *Times*, September 17,

1883, the editor favoured the invention with a similar opinion. Mr. W. H. Maw and his staff made five tests during nearly six months, of which the author here gives the last. An elaborate report of the same was published in *Engineering* for September 14, 1883, in which it was stated that the boiler embodies a number of novel features, and produces rapid circulation through the vertical tubes, the effect of the curtain being very marked, and that as a rule there was no trace of smoke.

RESULTS OF EVAPORATION TESTS.

August 31, 1883.

Duration, 8 A.M. till 5 P.M., 9 hours.
Steam pressure, maximum, 50 lb. per square inch.
Steam pressure, minimum, 39·5 lb. per square inch.
Steam pressure, mean, 45·5 lb. per square inch.
Coal, total quantity burned, 1015 lb.
Coal, quantity burned per hour, 112·8 lb.
Coal, quantity burned per square foot of grate (short bars), 8·68 lb.
Ashes weighed, containing fragments of coal and clinker for which no allowance was made, 39 lb.
Area of grate, 13 square feet.
Water, total quantity evaporated, 1150 gallons.
Water evaporated per hour, 127·7 gallons.
Water evaporated per square foot of heating surface, 2·2 lb.
Water evaporated per lb. of coal, 11·3 lb.
Temperature of feed-water, mean, 81·6° Fahr.
Temperature of gases measured in flue between damper and chimney, 290° Fahr.
Draught, mean, in inches of water, $\frac{5}{16}$ inch.

The National Smoke Abatement Association had two tests made by their engineer, Mr. D. K. Clark, who gave a minute report of the boiler in question, and from which the following figures (see p. 38) are taken. The report is dated January 18, 1884.

Mr. Clark concludes his report with the following remarks:—"On the first day the boiler was worked at the usual pace to supply steam for the daily requirements; on the second day it was forced by increasing the draught, in order to test still further the capabilities of the system. In point of efficiency the results compare favourably for the Engert boiler. On the system of firing for this boiler, which does not demand more than an ordinary degree of care in management, smoke can be entirely suppressed. Shortly after the two days' tests were completed, the boiler was opened in my presence, and I found on inspection that it was entirely free from scale, and was otherwise in good order. I may add, in conclusion, that in my opinion Mr. Engert has produced a steam boiler of much merit, and that he has made a new and effective departure in steam boiler engineering."

RESULT OF EVAPORATIVE PERFORMANCE AND EFFICIENCY OF THE ENGERT STEAM BOILER, LONDON 1883.

	1	2
Number of trial		
Date of trial	December 20, 1883.	December 21, 1883.
Temperature of boiler-house, average	59·3° Fahr.	57·3° Fahr.
Barometer average	30·03 inches	29·90 inches
Duration of trial	8 hours	8 hours
Average effective pressure per square inch in the boiler	41·6 lb.	36·6 lb.
Net quantity of coal consumed at trial	1064 lb.	1568 lb.
Net quantity of coal consumed per hour	133 lb.	196 lb.
Net quantity of coal consumed per hour per square foot of firegrate	10·23 lb.	15·10 lb.
Ash (no clinker) residue	74 lb.	84 lb.
Ash residue per cent. of net coal consumed	7 per cent.	5·36 per cent.
Average temperature of water supplied for consumption	73·5° Fahr.	70° Fahr.
Quantity of water supplied for consumption	202·5 cubic feet	236 cubic feet
Quantity of water per hour	25·31 cubic feet	29·5 cubic feet
Quantity of water per hour per square foot of grate	1·95 cubic feet	2·27 cubic feet
Quantity of water per lb. of coal consumed	11·85 lb.	9·37 lb.
Quantity of water per lb. from and at 212° Fahr.	14·18 lb.	10·96 lb.
Quantity of water per lb. of combustible	12·73 lb.	9·90 lb.
Quantity of water per lb. of combustible from and at 212° Fahr.	14·90 lb.	11·58 lb.

The interior of the boiler has also been inspected upon two occasions by the engineer of the London Mutual Boiler Insurance Company, the last inspection having been made on November 9, 1883. Upon each occasion the inspector reported the boiler to be clean and free from scale or deposit.

In conclusion, the author would submit that the defects of steam boilers and the evils of incrustation, priming, and bad circulation are largely, if not wholly, due to faulty construction, and that he has succeeded in remedying these defects. He submits this with confidence, not so much upon his own authority and experience as upon those of independent engineers, who have investigated the working of his boiler and have reported favourably upon it.

DISCUSSION.

Mr. PERRY F. NURSEY said that a few days ago he went to M[illegible]gert's works and inspected one of his boilers, arriving [illegible]e close of the dinner-hour. During the dinner-hour [illegible]e had been banked down, and he was present at the [illegible]. It was fired in the way which the author of the

paper had explained—by closing the damper and raising the curtain. A small quantity of smoke escaped from the chimney in the form of a thin cloud for, perhaps, from three-quarters of a minute to a minute and a quarter. He was in the works from half to three-quarters of an hour, and he afterwards watched the firing from a distance. After the first firing, of which he had spoken, no smoke whatever was produced from any subsequent firing. He should like to ask Mr. Engert what was the shortest time in which he had raised steam, say from a cold boiler. That would be rather an important point. Mr. Engert had referred to a paper which was read before the Society some years ago by Mr. Major, upon the priming of steam boilers. In that paper an invention was brought forward which referred to the use of petroleum fed in with the feed-water. After that paper was read, he (Mr. Nursey) took some little interest in the matter, and he found that petroleum had been tried on a small steamship belonging to the Brighton Railway Company which had been fitted with a boiler designed by Mr. Stroudley. Unfortunately that boiler was not quite suitable for marine purposes, and it primed very seriously. A small portion of petroleum was injected into the feed-water, by means of an apparatus for the purpose, about half an hour after they started running, and the priming was most effectually overcome. The quantity of petroleum was exceedingly small and it was moreover found that very little lubrication was needed in the engines. The apparatus was also applied to two steamers running on the Tyne, and with the same satisfactory results. He had not, however, heard of its further application, as there were other means of attaining the same end.

Mr. Barrow Turner said he should like to draw attention to the principle of supplying feed-water after having entirely deprived it of its air, particularly with reference to the influence which water so treated had in promoting explosions. It was commonly known that water might be heated very considerably above 212° Fahr. without agitation, and then when agitation took place the water rapidly flashed into steam. Some very remarkable explosions had taken place without having been satisfactorily explained, and it had been suggested that the cause of them was that the water had entirely lost its air and had got into that state in which it was liable to flash suddenly into steam. Hence the abstraction of air from the feed-water was open to question. The chief merit of Mr. Engert's boiler was its non-liability to priming, and he could easily imagine that it was a good boiler in that respect. The cause of priming was due to mechanical agitation of the water

by bubbles of steam rushing to the surface, and the very thin layer of water which Mr. Engert's boiler had over the fire and hottest part of the flue, by reducing that agitation to a minimum, would naturally tend to prevent priming.

Mr. P. W. D'ALTON said that as engineer to the Mutual Boiler Assurance Company he had been inside the boiler and had examined it critically. Its state of cleanliness was perfectly abnormal in his experience. He thought a great deal was due to the care with which the boiler was used. He had never met with a boiler more carefully treated than Mr. Engert's, in the method of firing, and in the care which was taken to supply good and pure water. Some steam users did not appear to pay the least attention to the condition of the water. He had never seen Mr. Engert's boiler under steam. With reference to Mr. Engert's idea as to closing the damper every time they fired, he was afraid there were not many steam users who would adopt it. He should think that marine engineers especially would have a bad time of it if they had to close the damper every time. It would make a serious difference in the time that a voyage occupied, though it was all very well to close the damper in cases where the engineers were not pressed for time. Mr. Nursey had asked how quickly Mr. Engert could get up steam. According to his (Mr. D'Alton's) experience, people got up steam a great deal too quickly, and boilers were thereby worn out in a very short time. Of course it would be interesting to know how quickly steam could be got up, but beyond that he objected to push a boiler to get steam up quickly. He was sure that in time they would hear a great deal more of Mr. Engert's boiler. It appeared, however, to be a difficult boiler to make, and he should think that for that reason it would be an expensive one.

Mr. SCHÖNHEYDER said the author had stated that boilers evaporated only about one-third, or one-half, of the amount of water per lb. of fuel which they ought to evaporate. He thought that very few in the meeting would agree with that statement. In country districts, where the fuel was very inferior, the evaporation no doubt was very low; but that was the fault of the fuel, and not the fault of the boiler. The author had stated that boilers when fitted with Galloway tubes evaporated only about one-half the proper quantity of water. He (Mr. Schönheyder) had made many tests of such boilers, and found that the evaporation was about as good as could be expected. As to the accumulation of gases in boilers, he thought that that idea was exploded long ago. If a gas could

separate itself from the steam it would mix with it again on account of the circulation of the steam which was going on in the boiler. To suppose that the gases, because of their greater specific gravity, would accumulate, was as great a fallacy as to suppose that in a room, with its air in motion, the carbonic acid gas would necessarily accumulate along the floor. That would be quite contrary to the theory of diffusion. If the gases could accumulate, the boiler would at last be full of nothing but gas; and he thought that if the accumulation took place, and could possibly do any harm, boiler explosions would be more frequent than they were. Years ago when less was known about the causes of boiler explosions many of them were attributed to the accumulation of gases. In the particular boiler which Mr. Engert had described there were a great many novel points, and a great deal was claimed for it. In connection with the absence of smoke he was sorry to see that the paper did not say a word about the quality of the fuel which was burnt. Had Mr. Engert tried some of the hard steam coal, as a very smoky coal supplied to the London district was generally called, or had he tried small coal? Mr. Clark in his report had not said a word about the quality of the coal, and that was a very important omission. If the arrangement for purifying the feed-water was a really effective one, all due credit should be given to Mr. Engert for it. It was well known that they could not separate the carbonates from the water without increasing the temperature to about three hundred degrees. If the sulphates and the carbonates could be separated from the water by the simple apparatus described in the paper, very great merit was due to Mr. Engert; perhaps that gentleman would state whether he had found that the lime which was contained in the water was found in the tank and was blown off from it. It would also be well for the author to state what kind of water he used in the boiler. The boiler contained many novelties of construction, and he thought that it had some merits. No doubt the water surface from which the steam was disengaged was very large, aud therefore they might count upon an absence of priming. The small tubes across helped the circulation in the same way as the Galloway tubes helped it. But it seemed that it would be a most difficult thing to make a boiler of that description, and the paper did not give any clue as to how a man could get into it. He thought that a boiler-maker who had to lie between the tubes and tighten them up would have a very lively time of it. The furnace which was shown in the drawing was something very novel, and, as he had said, he should like to hear something of its having been tried

with smoky coal. The construction of it was contrary to all experience. He did not quite understand how the ashes were got rid of below the firebars. There appeared to be a bar in front.

Mr. ENGERT said that the ashes fell out.

Mr. SCHÖNHEYDER said that the paper referred to the advantage of having oval flues. There was another well-known boiler-maker who constructed flues with oval bottoms. That was very well so long as the boiler-flues were clean; but when soot and ashes began to accumulate, the bottom of the flues became flat, and the oval shape was quite lost. He could quite understand that the closing of the damper during firing was a great advantage. The damper ought to be always partly closed at such a time. He knew that a very large percentage of fuel had been saved in that manner, but it was difficult to get stokers to do it. The closing could be effected by automatic means, and when that was done a great advantage could be expected. The results obtained in testing the boiler had surprised him very much. He had never seen such high results, except perhaps in boilers set upon Mr. Livet's system, and he thought that doubts had deservedly been thrown upon the tests made on those boilers. As to the tests now stated, the fuel must have been wonderfully good, but he believed that neither Mr. Maw nor Mr. Clark stated what fuel was used. He believed that the highest theoretical evaporating power of Welsh coal was 15 or 16 lb. It would be very useful if Mr. Engert would add to his paper a statement of the sort of coal which was used in his experiments.

Mr. NURSEY said that when he saw the furnace at work, it was fired with ordinary hard steam coal.

Mr. ENGERT said that hard steam coal was used in Mr. Clark's trial. They could not use navigation coal, as the furnace was too low. It required a large space, in order that the coal might be used in lumps, and gradually warmed. When that was done, the coal opened gradually out. The space was too small for that in his furnace. If there was more space in the furnace, navigation coal would be preferred.

Mr. F. E. DUCKHAM said but for his own experience to the contrary he would have been made somewhat anxious by the author's assertion that where mechanical stokers had been tried they had been abandoned, for he had recently ordered such apparatus to be fitted to four Lancashire boilers now being constructed for the Millwall Docks Company. He was, however, comforted by the knowledge that he had advantageously employed mechanical stokers for some years. These had indisputably

enabled the same amount of work to be done per ton of coal as when the boilers were fired by hand. But the apparatus required small coal, costing 11*s.* per ton, instead of ordinary steam coal at 15*s.* 3*d.* This machinery, which had been supplied by the Chadderton Ironworks Company, was cheaply maintained, continued to work well, and he had as yet discovered nothing to suggest its being abandoned. If, however, the stokers were removed as useless to-morrow, it was satisfactory to know that they had not only paid for themselves, but had produced a saving in coal alone of some 600*l.* per annum. In addition to reducing the cost of fuel, the labour of firing and smoke produced were considerably less. With respect to incrustation, he had found a coating of tar inside the boiler most efficacious, impurities which formerly caked hard upon the flues now settled at the bottom of the boilers, and could easily be cleared out. The same boilers ran double the time without cleaning. The boiler which had given him most trouble by priming, was one of a portable engine which took steam from immediately over a flat firebox, something like that of Mr. Engert's boiler. That did not support the theory that priming was to be avoided by having a flat flue a short distance below the surface of the water. He thought ample steam space, and a good dome, whence the steam could enter the steampipe well above the water level, the best preventatives of priming.

Mr. H. G. FRASER said, with regard to the cost of Mr. Engert's boiler, that in the present day purchasers were not so particular as to the first cost per ton of a boiler as they used to be. Price was not regarded as being so important an item as efficiency. He thought the cost of Mr. Engert's boiler would compare favourably with that of any modern form. As to the difficulty of getting into the boiler, there was a space of about 14 inches between the flues. The vertical tubes were readily put in position. They were taken in and out from the top, and the bottom ones were all taken in and out from the 14-inch space between the two flues. He did not think that in Mr. Engert's boiler there would be sufficient room to get underneath the bottom flue, but difficulties of that kind might be easily got over by adding an inch or two here and there. He believed that Mr. Engert had gained a great deal by being careful to prevent the admission of cold air during stoking and firing. It was his experience that if a self-acting damper was made to close easily (or partially close) behind the bridge, when the door was opened during the process of clinkering or firing, the cold air which was then admitted chilled the flues to such an extent that a large quantity of coal was consumed in recovering

the temperature which was in the flue before the coaling took place.

Mr. HARRY OLRICK said that some years since he had a rather disagreeable experience of putting steam through firebars. In the case of a Cornish boiler, he found that nearly the whole power of the boiler was consumed in supplying steam to produce combustion. However, the results arrived at by Mr. Clark and Mr. Maw with regard to Mr. Engert's boiler could not be questioned, though they were certainly very remarkable. Looking at the boiler generally, he could hardly understand why there should be such a good result. As to its construction, he should not like to have to take out any of the tubes from the bottom, especially if they were screwed in. The boiler, evidently tested under the best possible conditions, with good water and careful stoking, gave results that were most excellent. The question was, what result that boiler would show after being run for seven or eight years, with the surfaces both inside and outside coated to a great extent, and with cold water pumped into it. Some-time ago Mr. Schönheyder tested some boilers for him, Mr. Olrick, and found that after seven years' working, although the surfaces had naturally become dirty, the boilers were evaporating 10·93 lb. of water per lb. of coal, from and at 212° Fahr., using cold water as the feed. The boilers were Field boilers. The circulation in them was about as perfect as anything could be, from the fact that they separated two columns of water, and permitted the colder water to have a free chance of displacing the lighter column. He believed in Mr. Engert's boiler the heating surface was about five hundred square feet, and that roughly speaking he was evaporating about twenty cubic feet of water per hour. That was not a very large quantity for the size of the boiler, taking into consideration that he had got a very expensive brick setting, and either a very expensive chimney, or still more expensive steam jets. He should like to know if Mr. Engert had found any difficulty in cleaning out the tubes.

Mr. ENGERT, in replying upon the discussion, said he had raised 40 lb. of steam in three-quarters of an hour with an ordinary fire when the boiler had stood for three nights and two days, and the water was almost cold. As to the air being taken out of the water, the subject had been for years under the consideration of scientific men. It had been said that by means of boiling the water in the boiler, 70 per cent. of the nitrogen was ejected with the steam, and that set free the oxygen, which did the greater pa[illegible]e damage in a boiler explosion. It must not be forgo[illegible] in the Galloway tubes incrustation took

place because the tubes were conical and steam was formed within by the heat penetrating and leaving the solids behind. That in fact was well known. He had spoken to many engineers, and their testimony was that Galloway tubes had actually burnt through on account of the corrosion and incrustation within, as they could not be cleaned. He had no objection to Galloway tubes, or the various other tubes, but when a tube was long and conical the heated water therein expanded and steam was formed. That was a very different thing from the short vertical tube, in which no expansion could take place. The water was over-heated, and by the short vertical tube it was driven out in rapid succession, and on the top the steam was formed, leaving the tube clean. The boiler was fed with the river Lee water. His other boiler was fed with the same water in the ordinary way, and every three months it required three or four days' chipping. In the case of his new boiler he had never used anything for keeping it clean, except a little soda ash, and merely washed it out. What he had said respecting mechanical stokers was not his own statement, but a quotation, and he was certain he could find cases similar to those mentioned. The cleaning between the two tubes in the flues in his boiler was very easy. He had a machine similar to a chimney-sweeping apparatus, and that was put together and the boiler was cleaned with the greatest ease. As to the cost of the boiler, it was made at the same ratio as boilers of other shapes with tubes, and the tubes could be taken out at any time if necessary.

The PRESIDENT said they had listened to a very interesting paper. It had touched upon various points in connection with boilers and boiler-making, besides their cost and the consumption of fuel in their furnaces. They had also been reminded of imaginary gases which had sometimes been the supposed causes of explosions. It seemed as if the gases in the boiler cropped up as a convenient reason for explosions when nobody knew their real cause. He had seen a small boiler with glass windows at each end; and by putting a light at one end, and looking through the other, and raising the steam, he could see how the action of coiling took place, and that experiment was exceedingly instructive. The water remained perfectly quiet until the valve was raised and allowed an escape of steam. Then immediately water entered into a state of violent ebullition. That showed that water could be raised to a high temperature and yet remain equally still as in the spheroidal state, and then any lowering of the pressure caused a very large quantity of steam to be set free from the water at a moment's notice. If the same experiment were tried on a large boiler the effect

would doubtless be the same as in a small one, and would tend to show how extremely violent the ebullition became, especially when steam was taken from a single opening or from a contracted area. Mr. Engert had arranged a very large surface from which he could take the steam, to prevent any violent ebullition of water and the carrying over of water in a state of fine mechanical division with the steam, or the worse evil of priming. The old beam engines were always placed high above their boilers, and if any water entered the pipes, its natural tendency was to return to the boiler; but in the present day engines were too often put on the floor, and any water passing over from the boiler necessarily flowed into the cylinder of the engine, to the destruction of economy if not of the engine itself. In that respect he thought the old engineers were in advance of those of the present day, for they knew quite well how to prevent any injury to their work by spray passing over with steam, whereas the modern users of engines too often neglected the most obvious precautions.

April 7th, 1884.

ARTHUR RIGG, PRESIDENT, IN THE CHAIR.

AN INTERNATIONAL SYSTEM OF MARINE COURSE SIGNALLING.

BY CAPTAIN WM. B. BARKER, U.S.A.

AT a time like the present, when the attention of the Legislature and of the whole country, if not of every country possessing a mercantile marine, is directed to the question of increasing the safety of navigation, it will not be out of place to bring before the Members of this Society a means whereby the author conceives that safety may be materially enhanced. It is true that the broad question at issue is the loading of cargo vessels with regard to their stability, which question—that of stability—is a new one, and as recently stated in the *Times* by one of your Honorary Members, Sir Edward Reed, of its bearing on the loss of missing ships and their crews for years past, when carrying grain and other homogeneous cargoes, "probably neither the owner, nor the builder, nor the underwriter, nor the master, nor the mate, nor the crew, nor the Board of Trade (until recently) ever dreamed." It is also equally true that there is another cause at work bringing disaster to our ships, especially in times of fog, and that is the very incomplete and inefficient system of signalling which obtains at sea, and of which the author has had sufficient experience to justify him in condemning it in the strongest terms. It is this latter phase of this most important public question that he proposes to deal with this evening, first pointing out the merits and demerits of the sound signals at present prescribed for the guidance of vessels in fogs, the same being recognised generally by the mercantile world, and afterwards describing his own mechanical and automatic sound signalling apparatus, and his A B C system of course signalling.

First, then, the ordinary system. For ocean-going steam vessels the sounds are as follows:—One prolonged blast of a steam whistle when under way surrounded by fog, at intervals not exceeding once every two minutes. Should it be deemed

necessary to deviate from the course being steered, if to the right, that is to say if the helm has been ported, one short blast. If to the left, using starboard helm, two short blasts. If moving full-speed astern, three short blasts in rapid succession. In dealing with the first signal, one prolonged blast, as prescribed in Article 12 (*a*) of the rules and regulations issued by the Committee on the Rule of the Road at Sea, and internationally recognised, it will be necessary to draw attention to the fact that the vessel making this signal is entitled to be moving on any one of the thirty-two points of the compass. The officer in charge making this compulsory signal, is also governed by what is internationally known and recognised as the rule of the road at sea. This rule of the road simply defines the right of way to each vessel when they meet, giving one the right to hold a steady course, and instructing the other to pass clear, regardless of nationality. It will here be necessary to proceed to digest this rule of the road as it exists today, giving it (wherever found) all the merit due to it, but pointing out its radical defects and lack of comprehensiveness for the due fulfilment of the purpose for which it is ostensibly designed. In broad daylight the officer in charge of a steam vessel crossing at right angles is instantly alive to the fact that the crossing vessel has the right of way, and that it is his duty to pass clear of her. Should she be moving parallel with him, and on his starboard bow, it becomes the duty of both to pass clear, as they undoubtedly would in broad daylight. This is all very well when the vessel can be seen; but may we not ask why one vessel moving through fog should be conceded a right of way when in close proximity to another, unless the first makes known the approximate course she is steering, for the reason that in some instances starboard helm is required to pass clear, at other times port helm, in order to achieve that result? One short blast may be signalled and the helm ordered to port, at the same time inviting destruction, whilst if the course of the vessel whose signal caused that alteration had been known to the one making it, two short blasts might have been sounded, and the helm ordered to starboard. It is therefore fair to conclude that one prolonged blast of a steam whistle in fog is only serviceable if used to call attention to a steam vessel in distress, and should at all times be approached with caution.

Some few months since the *Morning Post* published an article written by Captain T. G. Bowles, who, from the manner in which he handles the question of the rule of the road at sea, must convince nautical men that he fully realises the import-

ance of a more simple and effective system by which officers in charge of vessels may be enabled to communicate their intentions to each other. Captain Bowles writes:—"In conclusion I would say that the suggestions I have made are the results of my being driven to desperation by the confusion which the existing code presents, and by the difficulties I have myself experienced when at sea, and responsible for the conduct of my vessel, in referring to, collating, comprehending, and acting upon, the present rules. If I be charged with presumption in setting up new rules of my own in opposition to those laid down by the Orders in Council, I would humbly submit that it is probably less presumptuous, and certainly it is more useful, to submit alternative rules, than merely to criticise and condemn those now existing. And in this, which is a practical matter, it would be at once idle and injurious to destroy by mere criticism, unless one were also prepared at the same time to submit rules which in their turn may be exposed to criticism. I present my suggestions, however, less for their own sake than in the hope that they may lead to a reconsideration and improvement of the present code, before the latter is riveted on us for ever."

It may be as well here to direct attention to various opinions as to the best methods of arriving at a solution of this important question, and in submitting some of the codes that have been suggested as practical remedies for the so-called international system just alluded to, to give, as fully as time permits, an impartial consideration to their merits and shortcomings. The first will of course be found to have been amply described, and dwelt on by their authors, whilst the latter have been ventilated at the meetings at which they have been brought forward, and by the Press, of this and of other countries. In the first place the author will refer to a paper read in 1883 before the Institution of Naval Architects, by Mr. J. Macfarlane Gray, a gentleman well known, and whose opinions are deserving of respect and attention, both by virtue of his experience and of his official position in relation to the mercantile marine. The paper in question was on "Fog Signalling," and after referring to what Mr. Gray justly designates "the crying need" there is of some international code of signals by which a vessel in a fog could communicate to vessels in its proximity, more accurately than is now done, the direction in which it is moving, he proceeds thus:—

"I have not any complete system of fog signalling to lay before you, but I know there are many now engaged upon this problem, and I have some remarks to make on details, which

I think of importance, to be attended to in any such system: and by bringing these before this meeting a discussion may be provoked, bringing out other important points and an expression of opinion as to the propriety of further international legislation. The following code of four blast signals can be taught in a few minutes to any one who can box the compass. It has only to be understood, it is not necessary or even advisable to commit it to memory. I will describe the signals as for a clear note and a trill, which I will call U and R. For clear and trill, may be substituted short and long, or high pitch and low pitch; the sounds U and R being the same as the words "you" and "are," the signals are easily spoken with these names for the blasts.

"Any eighth part of a given line can be indicated by the word left or right three times; thus, left right left would mean of the *left* half take the *right* half, and of that again take the *left* half. That would be the third eighth part from the left. In the same way, right left left would be the fifth, and right right left the seventh, from the left. If now, we had two such lines, we could indicate any of the sixteen parts by prefixing one word to tell which of the two lines the part is in. For the two straight lines we may substitute two curves, say the two semicircles of the compass card, and for right and left we have east and west; to distinguish which of the two semicircles the part is in we have to say north or south. We may now put in R and U for these. The first blast would always be read to mean north or south, and all the other blasts will be read east, or else west. As there is an R in north and a U in south, say R for north and U for south. East is on the right of a map; say R for east; and as there is a U (or rather two) in west, say U for west.

"Let the signal given be R U U R. The first blast R denotes the northern semicircle. The second blast U denotes the quadrant forming the western half of that semicircle. The third blast U denotes the four points forming the western half of that quadrant. The fourth blast R defines the two points forming the eastern half of the preceding four points, or the N W by W two points. The R U U R has evidently been read north west west east. When the principle of successively halving an already indicated arc and taking that half which is denoted by the blast is once comprehended, the mind itself provides a compass-circle diagram, which it divides, as indicated, at each blast, with the mind's eye fixed upon only the part indicated, without naming the parts. The compass circle having been divided into sixteen parts, through the cardinal

points, the middle of each division is a course with 'by' in it on the compass card.

CODE.

R U U U	W b N	U R R R	E b S
R U U R	N W b W	U R R U	S E b E
R U R U	N W b N	U R U R	S E b S
R U R R	N b W	U R U U	S b E
R R U U	N b E	U U R R	S b W
R R U R	N E b N	U U R U	S W b S
R R R U	N E b E	U U U R	S W b W
R R R R	E b N	U U U U	W b S

"There are optional signals of one, two, or three short blasts now in use, whereby a steamship under way is permitted to indicate to any other ship which she has in sight that she is taking a certain course authorised or required by the regulations. The only sound signals authorised for a steamer in a fog, when not having another vessel in sight, is a prolonged blast of the steam-whistle, at intervals of not more than two minutes. There is, therefore, really nothing in the regulations now to forbid or prevent the use of such a code as that I have described, but as it would lead to great confusion if different companies arbitrarily adopted different codes, an international sanction ought first to be obtained for some code—the one I have described, or a better one."

So far Mr. Macfarlane Gray; but whether his elaborate code is such as to meet the requirements of the case, or whether it might in use tend to even greater mystification than the present system, is for you to judge, always bearing in mind—and this is a point of crucial importance, both for your own thorough appreciation of the whole matter, and as a means and test of judging for yourselves—how far the element of simplicity can be claimed for it or for any other system which may be proposed. The author next submits another code, in strong contrast to that of Mr. Gray, which will be amply sufficient to illustrate the diversity of ideas on this subject, but which, nevertheless, tends to show that the authors are of opinion that a radical alteration is necessary. This code was communicated to the *New York Herald* in June 1880, over the initial "K.," the letter running as follows:—

"NEW YORK, *June* 17, 1880.

"*To the* EDITOR *of the* 'HERALD.'

"In view of the recent terrible accident on the Sound, and the narrow escape of the passengers of the *Anchoria* and the *Queen*, would it not be a good idea for captains of steam-vessels

in a fog to sound their course immediately after the fog-signal? By adopting one whistle as north, two as south, three as east, and four as west, a signal would be made easy to recognise, and a code formed which would require no study to learn, and which would be at once intelligible to any one familiar with the points of the compass. This code could be used equally well by captains of sailing-vessels, and by thus communicating their course, vessels would have no difficulty in keeping out of each other's way. For instance, 1, 1, 111 would indicate that the vessel was steering N.N.E., and 11, 1111, 11 S.W. by S. The only points where there would be any similarity of sound would be in N. by E. and N.E., S. by E. and S.E., S. by W. and S.W., and N. by W. and N.W. By blowing two signals for N.E., N.W., S.E. and S.W., this would be made sufficiently clear, and the danger of collision would be reduced to a minimum.

"To make my meaning clear I append the signals for the points of the compass:—

N	1	N by W	1.1111
N by E	1.111	N N W	1.1.1111
N N E	1.1.111	N W by N ..	1.1111.1
N E by N ..	1.111.1	N W	1.1111.1.1111
N E	1.111.1.111	N W by W ..	1.1111.1111
N E by E ..	1.111.111	W N W	1111.1.1111
E N E	1.111.111	W by N ..	1111.1
E by N	111.1	W	1111
E	111		
S	11		
S by E	11.111	S by W	11.1111
S S E	11.11.111	S S W	11.11.1111
S E by S ..	11.111.11	S W by S ..	11.1111.11
S E	11.111.11.111	S W	11.1111.11.1111
S E by E ..	11.111.111	S W by W ..	11.1111.1111
E S E	111.11.111	W S W	1111.11.1111
E by S	111.11	W by S	1111.11

"K."

Commenting upon this communication, the editor of the *Nautical Gazette* rightly observes that several attempts have been made to introduce such a system, but the difficulty to the mind of a practical seaman is that each operator would have his own measurement of time between the blasts and series of blasts which form a signal, and hence "K.'s" system would be impracticable, and even dangerous. To be terse, *there is too much of it.*

Having indicated the ordinary system of sound signalling at sea, and having directed attention to two propositions having for their object the improvement of this class of signals, the

author will in the next place describe his own invention, which is illustrated by the full-sized working apparatus before you, as it would be applied on board ship. The apparatus consists of three main parts, namely (1) a horizontal dial-plate, (2) an indicator and bell, and (3) a fog-horn, all three being in communication, as shown in Fig. 1 of the engravings. The dial, which has on it a fixed index always pointing ahead, is placed on the bridge, and is under the control of the officer in charge. The dial-plate can be revolved either to port or starboard, and on it are engraved the cardinal points of the compass, and the principal subdivisions, N.E., S.E., N.W., and S.W. This part of the apparatus is connected with the indicator, which is fixed in the wheel-house in a vertical position, immediately in front of the steersman, who requires no other guide than the index on it. When the officer in charge wishes to alter his course—say to port—he gives the bridge-dial a slight turn. This strikes one bell in the wheel-house, which tells the steersman to port his helm, the precise course he is to steer being indicated to him on the dial in front of the wheel. This dial has, in addition to the points named above, eight others, N.N.W., N.N.E., E.N.E., E.S.E., S.S.E., S.S.W., W.S.W., and W.N.W. Instantaneous communication is thus established between the officer and the helmsman in a direct manner, and there is no risk of any mistake, as there is in the verbal transmission of the word. But, beyond this, the course the vessel is steering can be simultaneously and automatically indicated to ships in her vicinity in a fog or at night by means of the fog-horn, which is fixed on the deck, and is also connected with the dial apparatus on the bridge. This fog-horn, which is shown separately at Fig. 2, consists of a cylinder, having a plunger worked by a rack and gearing, and being fitted with a series of cams and a valve to admit air. The horn is mounted on the top of the cylinder, and on the mechanism being operated, air is compressed and afterwards released by a series of cams, which cause the air to escape intermittently through a valve, and so out through the horn. The signals consist of long and short sounds in various combinations, which are reduced to a simple code of eight signals, giving the approximate course for the thirty-two points of the compass. Upon the officer turning the bridge-dial, the fog-horn is locked to the code signal for the particular course to which the ship has been altered, and it instantly emits the signal, which indicates to all other vessels within hearing the exact course she is steering. Moreover, the signal also indicates whether the ship signalling is a steamer or a sailing-vessel, for the system can be applied to either.

Such is the general character of the apparatus; but, before describing his code, the author thinks it might prove interesting to the Members if he described the construction of the apparatus

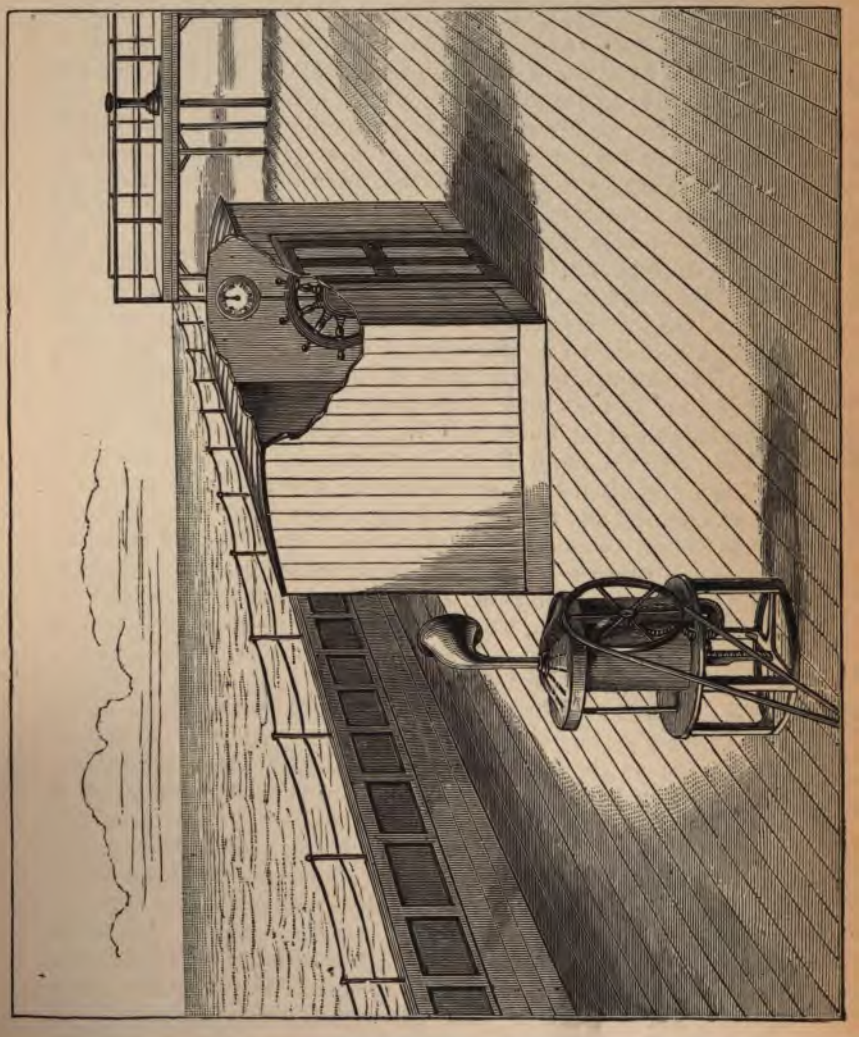
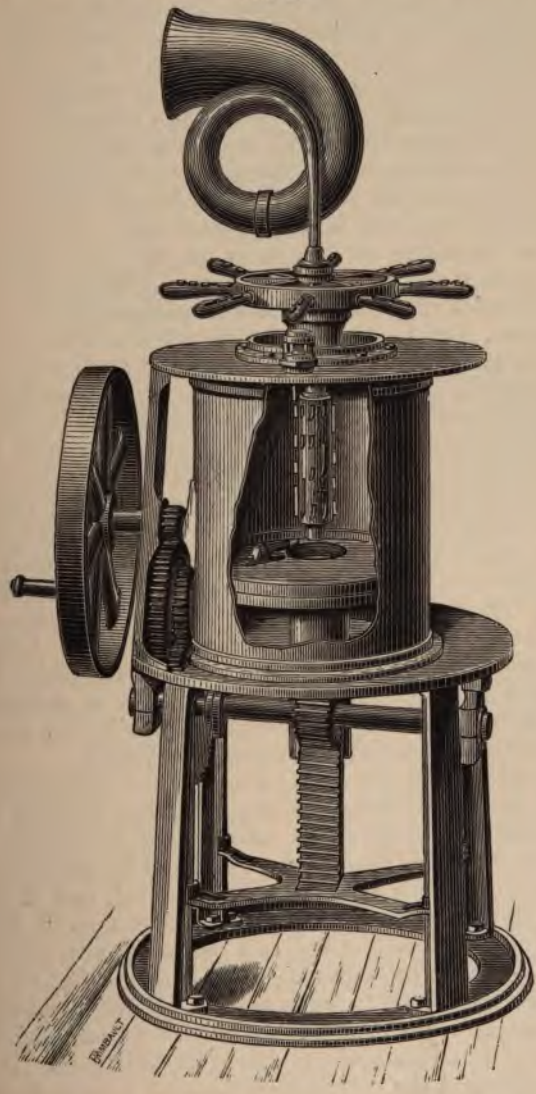


FIG. 1.

in detail. He would, therefore, observe, that one of the most important parts of the system is the disc or dial-plate, which, as already obser[illegible] is marked to correspond with the eight prin-

cipal points of the compass-card, which relieves the officer of thinking what signal is to be given for any compass course he

FIG. 2.



may instantly wish to change to, thereby saving time, without liability to error. In the centre of this disc is a hollow ball,

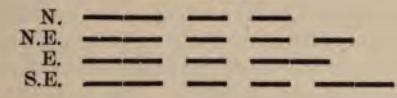
for holding a reed. A tube conveys the air to the reed by means of a port in the code cylinder, this cylinder being ground to fit air-tight, covering the pipe or tube leading to the ball, upon the top of which is the horn. The dial-plate ball and tube retain their position as locked to any particular signal, while the code cylinder is free to partially revolve, in order to open the port for admitting air to the horn. The cylinder containing the code cylinder and pipe is fitted with a plunger, having near its centre, and made fast to the rack, a tube or case for receiving the code cylinder, whilst the plunger is ascending, in order that the plunger may move the full length of the cylinder. Overhanging this case, is a trip lever with a roller, for the purpose of operating on the cams on the code cylinder, and which represent the signal to be given. The trip lever presses round and holds the code cylinder in position while a signal is being given, but trips after the signal has been given, thus closing the port until it is desired to give a fresh signal. When the plunger reaches the top, the entire signal has been given. The ratchet-wheel, which is loose on the main shaft, then instantly disconnects the series of geared wheels used for compressing the air, and a drop valve in the plunger causes the same to descend until a pin fixed to the bottom of the plunger comes in contact with the lever of the ratchet-wheel, when the series of geared wheels again become connected, thus causing the plunger to commence ascending, when the signal may be repeated. By changing the position of the dial-plate, a different signal may be given and repeated automatically. Our present regulations compel the use of a mechanical fog-horn on all vessels, but nothing is said about uniformity of signals, which, in order to ensure safety from collision, the author contends is one of the most essential features of any system.

With reference to his A B C course signal system, the author would observe that his code is compiled upon the basis of giving the *approximate* instead of the *actual* course, in order to simplify as much as possible the meaning conveyed by the signal given. It is from first to last systematically arranged, and is composed of eight signals, giving the approximate course for thirty-two points of the compass. All signals beginning with a long sound show the course to be eastward; those commencing with a short sound show the course to be westward. Signals ending with a short sound show the course to be northward, and those ending with a long sound show the course to be southward. If the first sound is long and the last short, the course is from N. to E. If the first is short and the last short, the course is from N. to W. If the first is long and the last long, the course is from E. to S.

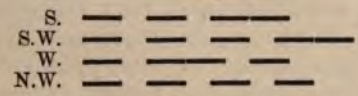
The first sound short and the last long gives positive proof that the course is from S. to W. It will thus be seen, as already stated, that the code is systematically arranged and easily mastered, as shown by the following graphic delineation :—

CODE.

Steering East.



Steering West.



Here, then, the author submits, is a perfect mechanical automatic arrangement and a perfect code ; one, moreover, which is not only as well adapted for sailing-vessels as for steamships, but which has a distinctive character for each, so that no failure to distinguish whether it be a steamship or a sailing-vessel from which the signal proceeds is possible. This distinctive character is produced by a variation in the note emitted by the fog-horn. For example, the steamer would give a blast of uniform tone, it would, in fact, play upon one note, whilst the sailing-ship would give alternately a high and a low note. Any code for international adoption should be arranged to suit the maritime nations of the world, and not merely the requirements of vessels entering or leaving English ports. The instruments should be alike on each vessel, and the code to be used in fogs the same. When we sight a vessel's light at night, not anything is known of her nationality. Nor do we care to know, so far as clearing her is concerned. All we want to know is, what does the officer in charge intend doing—hold a steady course or go to port or starboard ? This being so, how great the difficulty, in a dense fog, when we know of a steamer's presence, but nothing of the course she is steering, or the course she may be heading—when we hear her signal one blast to port or two to starboard, as the case may be. Article 12 (*a*) of the Rules and Regulations might instruct all officers of vessels, when surrounded by fog, to sound the approximate course the vessel was heading, instead of compelling them to sound one prolonged blast of the whistle when moving on any one of the thirty-two compass points, which only warns each of an approaching danger, and is only cleared by paying the strictest attention to the location of sound.

Having now directed attention to some of the different systems proposed for preventing collisions at sea in fogs, the author would observe that in his judgment it is necessary to have the two qualities of uniformity and simplicity internationally recognised before deciding on the adoption of any particular code. If every maritime nation used the same signal for the same purpose, then the mariners of England would speak an intelligible language to those of every other nation in the world, and the more simple such language or code can be made the better it will prove in the common interest, as the sounds would at once be understood and acted on. In fact, these two points of uniformity and simplicity are the most important factors we have to deal with, constituting, as they indisputably do, the gist and backbone of the whole question. This is at once apparent when we consider that at present, in endeavouring to clear a vessel, we are compelled to act on an opinion founded entirely on such an instantaneous judgment of her position as it may be possible to form from the one prolonged blast heard from her. In fact, there is no disguising the actual position in which under such circumstances the officer in charge is placed. He is risking a movement founded on a hasty opinion, hoping it may be right. Is it not, therefore, painfully apparent that he should be relieved from such anxiety and unnecessary responsibility as this uncertainty involves, by affording him the means of definite knowledge, instead of leaving the degree of danger a matter of opinion? It may be that he possesses experienced judgment, but which, to say the least, is liable to err, and from that error arises calamity. If a red light is seen on the starboard bow of a vessel on a dark but otherwise clear night, it is known that danger is threatened, and such precautions are taken to avoid it as the rule of the road lays down for the officer's guidance. But what is the situation when no red light is visible? And yet the vessel carrying it and exhibiting it occupies the same position relatively to his vessel as in the proposition the author has just suggested. What safeguard is a light of any colour at such a moment, when even seconds are pregnant with the fate of possibly hundreds of lives, if, in a fog, our warnings were derivable from colour alone. Let there, then, be sounds as intelligible in the gloom as colours are in the clear, and, combined with compass-cards, the same in principle on vessels of every nationality. With such a system let us see to what extent the change would operate for the better so far as the officer in charge is concerned. Under the existing conditions his probable state of incertitude has been shown. Under the altered conditions we have really a changed man; and

why? Simply because he has confidence in the order he transmits, and in the method of its transmission. The first he knows is the correct order, and the second he is absolutely aware cannot be tampered with, or altered, for the reason that his will actuates directly the signal itself, without the intervention of any person or thing liable to error, or the possible misconstruing of what is involved from his own construction of that which he hears. It is, in fact, much as though A responded to an intimation from B that he was going to John o'Groats by the information that he (A) was bound for the Land's End.

It must be evident to all that sound alone is the means by which messages may be transmitted in fog; at all events, there is not at the present moment any other method which can be said to be available for that purpose. The author does not even except lights specially designed for the purpose of overcoming the difficulty, which in many fogs would only be visible at a very short distance indeed. Even the powerful electric ray is not able to penetrate and illuminate the atmosphere at such a time sufficiently to enable us to rely on it as a means of avoiding danger. We should therefore make those sounds intelligible, otherwise vessels approaching each other would be simply playing a game of hide-and-seek. But, given a definite language and the means of speaking it, whether it be an English, an Italian, a Russian, or a Turkish vessel whose signal was heard, the various nationalities would at once and always understand each other.

It may be urged that some difficulty may still arise in localising the sound, and that a great deal may still be left to judgment in this respect. In fact, some hold the opinion that sound cannot be localised, and that one cannot define its exact position in a fog. Nor does the author think sound can be localised when proceeding from a steam-whistle which is the centre of a sound-wave which radiates equally all round the horizon; that is, with equal force in every direction. But from a properly shaped bell-mouthed instrument, capable of being turned in any required direction, the sound is bound to be projected with greater force, and with special concentration, in the direction in which the bell is turned, and this concentration and special direction is susceptible of largely increased value by the use of a sound-reflector, permanently attached to and moving with it. Officers as a rule look out for danger ahead or on the bow, and it is there the bell of the horn should point, but the steam-whistle will throw sound as far astern as ahead, unless placed close to, and in front of the smoke-stack.

In conclusion, the author would once more impress upon his hearers the vital importance of some well-defined system being made international. Whether it be his own or any other, in order to entitle it to such a proud position, it should possess pre-eminently the qualities of reliability in operation, and simplicity and universal intelligibility in the language it speaks. The adoption of such a system could not fail to reduce collisions in fogs at sea to a minimum.

DISCUSSION.

Mr. H. STOPES said he was an occasional traveller, and in that way only was subject to the risks of the sea during fog, but he had sometimes experienced great alarm when on board a steamship becalmed in a fog. He remembered that on one such occasion he was steaming among the isles of the Grecian Archipelago, and they not only had the danger of a very intricate channel, but also the constant apprehension that they should have vessels of various nationalities running into them. For seven or eight hours they were in a fog, and the signal was constantly sounded. While under the constant apprehension of a collision, it occurred to him that it was absurd that the only mode which they had of communicating with other vessels was by pulling a string and making a whistle sound. He thought that such a simple and ingenious and excellent system as that which they had just had explained to them, could not be otherwise than of great value to all if used. It seemed absurd that they should be subject to restrictions in the matter of the communication of ideas in consequence of there being no universal language. In this particular matter a universal language could be at once introduced, seeing that if Captain Barker's code was adopted, every man, no matter what his nationality might be, could readily understand the signals and the movements of all ships in his vicinity.

Mr. PERRY F. NURSEY said that he had watched the development of Captain Barker's invention with a considerable amount of interest for four years. Four years ago the invention was only developed so far as the signal-sounding apparatus was concerned. Since that time it had been brought to what he considered to be its present very perfect condition, by the addition of the means of signalling from the bridge to the steersman and sounding the signalling apparatus automatically. He thought there were none present who had seen the
hanism who would not agree that it was highly ingenious.
h regard to the nautical points, it would no doubt be

interesting to the meeting to hear the opinions of nautical men present, and he hoped that they would have the pleasure of hearing them on the subject. Having interested himself in the apparatus and in getting Captain Barker to read the paper, he had spoken to one or two nautical friends on the question, and they had expressed strongly favourable opinions with regard to the Barker system. He thought that all would agree that if this or any other system was to be of any practical utility, it must be made international, for upon a universal language depended the safety of the navies of all nations.

Mr. JOSEPH BERNAYS said he could understand the use of codes for the general purposes of sailing; but he should have thought that, when two vessels met each other, the mere fact of their going starboard or port would be quite sufficient to indicate to one another which way they ought to steer, and therefore he did not quite see why in a fog they should require more. He should like to know why it was that when two vessels were likely to meet each other a simple signal showing whether they were going to the right or to the left would not be sufficient, and why they must have a system of thirty-two signals to choose from, instead of only two or three.

Captain BARKER, replying to Mr. Bernays' question, said that at the present time steam-vessels moved through a fog upon any one of the thirty-two points of the compass, and always sounded the same signal, so that it was utterly impossible to tell whether they were approaching or going away, or whether they were overtaking. By the signals at present in use the captain of a vessel could not tell whether a steamer in his neighbourhood was crossing his bow, or simply running parallel with him. If he put his helm to port and gave a short blast, he might run right into the other vessel, or the other vessel might run into him. The object of a system of course signalling was to convey definite information as to the direction in which a vessel was going to steer. There was one point which he should like to impress upon engineers. When a steam-vessel was running through fog the officer in charge was standing on the bridge, and he was just as anxious to save his life as any man could possibly be; and he was also anxious to save the life of the engineer; but the engineer was down below attending to the orders which were received from the officer in charge. If a collision occurred and the vessel went down, the engineer would be likely to go down to the bottom with it.

Mr. PRINCE asked how far the sound of the fog-horn would reach.

Captain BARKER said that depended somewhat on the

amount of pressure per square inch. He employed a pressure of 14 lb. to the square inch; but he used the air very economically. The horn he exhibited could be heard 1¾ mile. By putting on a double-acting air-pump, driven by the same gear, they could easily get a pressure of 20 lb. per square inch, without making it too laborious for any man to work. A pump which he now had on one machine could with a slight alteration be made to compress the air from 20 to 25 lb. per square inch. He claimed that a signal could be heard from his foghorn for a distance of 2 miles.

He had hitherto been talking about fogs, but a great many collisions occurred at sea at night when the weather was clear; and as ships' lights were at present arranged they could be seen over a range of ten points of the compass. He had an apparatus consisting of screens so arranged that a ship's light would be cut off at thirty degrees, so that there might be less uncertainty with regard to the course she was steering. [Captain Barker here exhibited a model of the arrangement and described its application]. He added that in 1860 the Brethren of the Trinity House were discussing the subject of signalling, and one of them said: "It may be assumed that however well ships might be supplied with the means of making such signals, such is the negligence of seamen that they would refrain from using them at the only times when they could do so with advantage." The answer to that appeared to him to be that the extent of their use would be measured by the handiness and the simplicity of the signal itself. Ever since the year 1860 the Trinity Brethren had been endeavouring to obtain some method for preventing collisions at sea, but they had not found out anything yet. He, Captain Barker, first went to sea in 1853 and had been on the sea nearly ever since; and all that time they had been using the same kind of signal for sailing-vessels in a fog.

The PRESIDENT, in closing the discussion, said that it was a matter to provoke the astonishment of landsmen that the intelligent and clever men who had been going to sea for so many years had not succeeded in inventing some complete system of signals, whereas that had been done with regard to railways long ago. The necessity for an international arrangement had been very well insisted upon by the author of the paper; and there was no doubt whatever that if any international system ought to be adopted by the principal maritime nations of the world, Captain Barker's arrangement appeared to be the one for use, being simpler and very much to the point. Captain Barker had said it should not be adopted at

English ports alone, and that remark was perfectly true, but at the same time, any arrangement which would suit the English nation with its extended commerce, would tolerably well suit every other nation in the world. If they once began to deal with the subject by means of an international council they would come to almost hopeless confusion. For instance, the French would probably want something which seemed very scientific, and a great deal too clever to work. If England and the United States were to settle upon a practical system of signalling, the chances were that the other nations would adopt it. Then they would have a system of signalling at sea by which every one could tell the direction in which vessels were steering.

As a matter of some interest he had made notes of a few experiments which Professor Tyndall carried out in 1873, at Dover, to ascertain the permeability of the atmosphere during fogs and during clear weather. In those investigations Professor Tyndall found that a number of circumstances had entirely escaped previous observation, or at least had not been published. He ascertained that the permeability of the atmosphere to sound appeared to increase almost in direct proportion to the thickness of a fog. During a clear day, when they could see the signals perfectly, they could hardly distinguish the sound for more than one-tenth of the distance that it would be heard during a fog. For instance, on the 2nd of June, 1873, the day was brilliantly clear, and the steam-horns which were used in those experiments were heard only two or three miles. On a succeeding cloudy day they were heard beyond nine miles. On the 25th of June, guns which under the same circumstances were inferior to horns were heard at a distance of 5½ miles. On the 1st of July, which was a dull day, a rotating horn was heard at a distance of 12¾ miles. On the 3rd of July the cliffs could be seen at ten times the distance at which they were visible on the 1st of July; and yet a horn was heard at a distance of only 2 miles; and a singular effect was experienced, viz. that the sound was reflected back towards Dover from a transparent atmosphere. The 8th of October was a fine morning, and the horn was heard at only 5½ miles. Later on in the day there occurred a violent storm of rain and thunder; and the horns were then heard during the intervals, at 7½ miles, better than they were heard before at 5½ miles. It was discovered that by varying the pitch of the horns at different times on the different days a considerable change was made in the distance at which they became audible. From these experiments several conclusions were drawn. One

was that sirens transmitted sound better than any other instruments in rough weather. Another conclusion was that rain, fog, and storm, so far from hindering sound, were rather conducive to its transmission. It was a singular advantage with regard not only to Captain Barker's, but to every other system of signalling, that, as lights became less visible, the penetrative power of sound increased. The laws of acoustics seemed to come in singularly well in this respect, in accord with those of light, in assisting the mariner if he would only take advantage of the laws which existed for his benefit. The meeting was very much indebted to Captain Barker for his interesting description of the signalling apparatus, and for the experiments by which he had illustrated its operation.

May 5th, 1884.

ARTHUR RIGG, PRESIDENT, IN THE CHAIR.

THE ENGINEERING OF MALTING.

BY H. STOPES.

FEW extensive industries in this country have called into play the inventive faculty of the engineer so little as malting. Probably no other industry has dealt for so many ages with vast quantities of material, entirely independent of the aid of even the simplest of the mechanical motions. The majority of maltsters for ages have gone on making malt, generation succeeding generation, apparently content to perform the whole work by manual labour, aided by two, or at the outside, three tools of the simplest and rudest character. The chief implement was probably the first that civilised man made, or perhaps, more correctly speaking, that first helped to civilise man, viz. a shovel or spade of wood. All this, however, is now changed. Malt-houses are rapidly becoming filled with appliances and implements of a high character, and the buildings are beginning to be regarded as a fit subject for scientific consideration by engineers. We can accordingly now speak of the engineering of malting.

As this is, however, the first paper that has been presented to this Society upon the subject, it may be desirable briefly to describe what malting is, and to glance at the salient points of its history. Malt is *any* corn, grain, or seed which can be artificially germinated within certain limits, so as to admit of particular influences affecting the constituents of such corn or seeds to be developed at the will of the maltster. The analyses given in the table on page 66, show the value of the changes induced by malting.

The most noticeable feature is the slight amount of starch actually converted to sugar in malt, and the readjustment of the molecules composing the starch and soluble albuminoids, commonly called diastase, in such a form that the conversion of starch into sugar is readily effected by the addition of moisture; hence the apparent sweetness of malt to the palate.

COMPOSITION OF BARLEY AND MALT (OUDEMANS).

—	Barley.	Pale kiln-dried.	Malt sun-dried or air-dried.	Amber.
Starch	67·0	58·6	58·1	47·6
Dextrin	5·6	6·6	8·0	10·2
Sugar	0·0	0·7	0·5	0·9
Albuminoids	12·1	10·4	13·6	10·5
Cellulose	9·6	10·8	14·4	11·5
Fat	2·6	2·4	2·2	2·6
Ash	3·1	2·7	3·2	2·7
Products of torrefaction	0·0	7·8	0·0	14·0
	100·0	100·0	100·0	100·0

The curious and beneficial properties communicated to seed, and especially some of the Graminaceæ, by germination were discovered at a very early stage of man's development. No positive evidence of the existence of malt has yet been furnished from the *débris* of the Swiss Lake dwellings, but it most probably will be some day. Many classical writers of antiquity allude frequently to the preparation, use, and effects of fermented liquors, made from barley, wheat, &c., by the ancient races of Europe, Asia, and Africa. Herodotus attributed the invention of beer to Isis, wife of Rameses II.; Pliny, Aristotle, and Strabo speak of it, and Diodorus affirms that some beer was so palatable as to be scarcely inferior to wine. As Pliny speaks of liquor made from steeped corn, and Wilkinson found traces of malt at Thebes, we may fairly conclude that malt was generally used, and consequently it has a very high antiquity.

All the nations of Europe in earlier ages made beer, and the consumption of malt in Europe alone has been truly immense for upwards of 2000 years. The process of manufacture described by Geopinus indicates that it was, to all intents and purposes, made by the ancient Britons in the same manner as in many hundreds of primitive maltings in Europe and our own country at the present moment. Maltings are working at this hour which employ no other tools and do not make any better malt than described by William of Malmesbury, made by the monks of many midland monasteries in the time of Henry II. of England.

At the time when malt liquor formed the staple and almost exclusive drink of the Teutonic races, the consumption of malt was, as already noted, large. Two centuries ago, when the population of this country was only 5,000,000, the quantity of malt made was 30,000,000 bushels per annum. One century later,

when the population was under 10,000,000, the output of malt upon which duty was paid was only 28,000,000 bushels; and during the last year of assessment of the malt-tax (1881), with a population of nearly 35,000,000, the amount of malt made in Britain was only 60,000,000 bushels, producing a revenue to the State of 8,000,000*l.* sterling as beer duty alone.

The quantity of malt consumed in Europe and America is, approximately, considerably over 200,000,000 bushels per annum —for, in beer-making only, Great Britain consumes annually over 50,000,000; Austria and Germany, over 60,000,000; France and Belgium, 20,000,000; Russia, Holland, Denmark, Sweden, Norway, Switzerland, Italy, and Greece, collectively, over 13,000,000; and America, over 24,000,000. There is also a large quantity used for making spirits, bread, cattle-feeding, and many other purposes. At the lowest computation, the capital embarked in malting may be estimated as follows:—

Value of buildings	25,000,000*l.*
„ appliances and tools	5,000,000*l.*

—a total of 30,000,000*l.* permanently invested. As the raw material can be purchased only once each season, the value of the corn used is not double the working capital employed, so that we may assume it to be at least 25,000,000*l.* The number of men actually engaged in the business cannot be under 30,000. These figures indicate the importance of the industry. Owing to the repeal of the malt-tax throwing open the trade in such a manner that every legal restriction to rational working is removed, an opportunity is afforded to the maltster to call in to his aid the inventor and engineer. This many maltsters are already doing, and the trade is undergoing a complete revolution; for, with improved facilities for rational working, scientists are aiding practical men to discover the right conditions that should surround any corn during the process of conversion into malt, and devising such apparatus and machinery as are able to cause and control these conditions when determined upon.

The Engineering of Malting.

This may be conveniently divided into two sections:—

I. The buildings necessary for making malt, and their construction.

II. The apparatus and implements used by maltsters.

Both sections may be subdivided into the natural classes of—

(A) The ordinary English and Continental systems of malting.

(B) Pneumatic malting.

(C) The manufacture of black, amber, crystal, and other special malts.

(D) The gelatinisation of rice or maize and other processes of preparing grain for brewers' use.

The English system, briefly, is steeping corn in an open vessel, germinating it upon flat exposed floors at very shallow depths, and drying upon an open-fire kiln with single floor at from nine to twenty-one days after steep. The Continental system differs in steep, position and depth of floors, time and mode of drying. Pneumatic malting is absolute control of the conditions of the air supplied to growing grain, and its consequent modifications of growth.

Maltings and their Construction.

Maltings belonging to classes A, B, C, and D have only two things in common: they must all be able to receive and moisten grain, and finally dry it. All malt-houses belonging to classes A and B have this further in common: they must secure conditions more or less favourable for the proper germination of corn up to a certain limit, prior to the drying process, within a given range of temperature. These conditions are all subject to definite limitations of heat and of circulation of air. Simple as they appear to be, they present scope for an almost infinite diversity of arrangement of building and modes of construction. Coupled with the due consideration of solidity of building and economy of labour, they cover the whole sphere in which the engineer can serve the maltster, or, in other words, they embrace the whole of the engineering of malting malt.

The simplest form of malt-house possessing any capacity for work is a plain two-story building, having attached to it a kiln or drying-house, and consisting of a ground floor of clunch, a brick steeping-cistern, and a first-floor of timber, with or without partitions for separating the stored grain or malt. The only implements are a wooden shovel and a winnowing-fan or sieve to separate the roots or "combs" from the malt prior to its use in the brewhouse. The author has seen malt made in Italy in an open court or *loggia*, where the barley was steeped in a tub, allowed to germinate upon the stones in the open air, and dried in a small lean-to building, with only a hole in the roof for the exit of smoke and vapour. This was furnished with a floor of perforated sheet iron and a furnace similar to that used under an ordinary washing copper in an English scullery. Even more primitive operations are performed in Nubia, as there millet, a malted, is dried in the sun. Such rude malteries concern

us only so far that they occupy the lowest end of the scale, and indicate the necessity for moisture, growth, and curing or drying, the three essential conditions of making malt. The opposite of these houses is the grand malt-house of M. Bonnette, of Troyes. The vast diversity of buildings filling in the various grades of the long scale of which these form the ends, are of use to the engineer who knows them all sufficiently to direct him in the scientific appreciation of his duty when called upon to construct a malting, to devise the machinery to minimise the labour of its working, or to invent and construct such apparatus as shall absolutely control the conditions of the material treated, throughout the whole of the period that it is in the building.

The best description of building for any malt-house is a combination of stone, brick, concrete, iron, and timber, as each of these materials possesses advantages special to itself for each particular purpose to which it is adapted; nevertheless, other materials can be used. A malt-house may be constructed in almost any position, and of nearly every form of building or arrangement of separate buildings that may appear to suit special sites or particular positions. A right consideration by the architect or engineer, when he is in a position accurately to estimate the force and true value of the conditions which have been specified, would prevent the absurd and wasteful structures that can be so frequently encountered in all parts of Europe, in which malt of an inferior character is necessarily manufactured, owing to the impossibility of maintaining, throughout the somewhat lengthened process of making malt, all, or perhaps any of the essential conditions.

A good malt-house of fair size belonging to class A is most conveniently and favourably worked if it consists of one main building of three stories—two kilns, and a corn or malt store. If adjacent to a brewery or distillery, the basement may be used as a cellar or bonded warehouse, and power may either be taken from the brewery or other engine, or (preferably) steam conducted from the boiler of the brewery to a small separate engine fixed in the malt-house. If the building is isolated, then a small and separate engine and boiler is desirable.

Power is of little real utility in any malting of this class steeping less than 400 quarters per month. Those steeping from 400 to 600 quarters per month can conveniently be worked by a gas or hot-air engine, but every malt-house steeping 800 quarters and upwards per month should possess steam power. Every size and description of malting belonging to classes B, C, and D should have power, preferably steam, although some are worked by manual labour. Under certain favourable conditions water

power is applicable, and it is lamentable to find in how very few cases it is utilised. Hitherto, engineers have been called almost exclusively to advise upon and construct the motors in maltings, and the appliances for cleaning or moving grain. The day has at length dawned when their opinions and advice as to the best modes of securing and rightly maintaining the conditions already set forth as necessary are of great and distinct value. The field is not a very vast one, yet it is sufficiently great to offer ample rewards to a number of such engineers as are fitted to fill it, and an industry which in our land has almost stood still for several centuries will feel the quickening impulse of well-trained scientific thought directing its operations, in preference to the crude rule of thumb or practical ignorance that until so very lately pervaded it. It will be desirable now to proceed to point out what the engineer is called upon to do step by step through each division into which, for convenience, the subject is divided—commencing with the simplest.

Section I., Class A.—English Malt-houses, Old Plan.

Malt-houses of this class are very rarely built of a size smaller than what is technically called 15-quarters steep, i. e. they steep or wet every three and a half or four days 15 quarters of grain, which gives a capacity of 120 quarters per month of malt made.

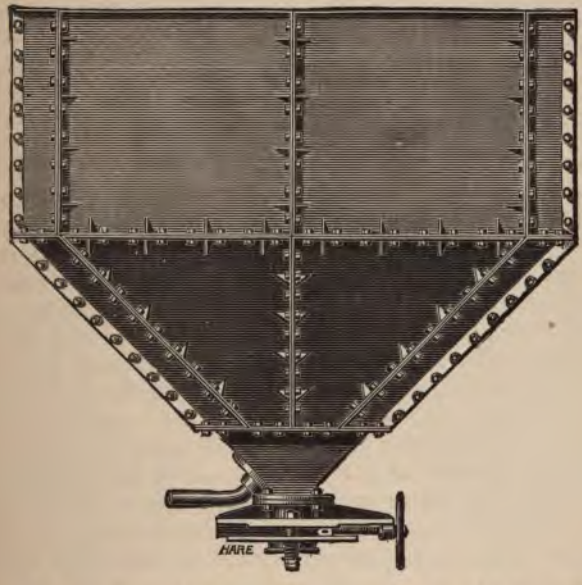
As houses of this character usually work for only seven or eight months, their total capacity falls short of 1000 quarters per annum. In many cases, houses of this size are worked by one man entirely, who for the four summer months commonly follows some other craft, such as thatching, bricklaying, or the like. When malting commences in October, his duty is to receive the barley, screen and pass it into the cistern, steep, then couch and floor it, raise to the kiln and dry it, tread, screen, store, and again screen it, and measure into sacks for use. All this, involving constant attention, skill, and care, is performed for the wage of from 14*s.* to 20*s.* per week, or say from 28*l.* to 40*l.* per annum. The value of the malt made on an average would be over 2000*l.* The difference in value of such malt, if well and intelligently made, or carelessly attended to and spoiled, would be from 200*l.* to 500*l.* or more, apart from the danger to those who drink the inferior beer produced.

vent such damage and loss, and to give the maltster the aid to perform properly his arduous and onerous duties, ıeer has to see to the following points:—

e should be of strong, solid construction, and consist

of two floors and a kiln, or if space is limited, of three floors. The shape and size are always ruled by the position of the house and the nature of the site, but they should rigidly follow the relative proportions that experience has taught to be the best for the purpose of making malt; that is to say, the length of the growing-floor should always exceed the breadth by at least two to one. The growing-floor should be below the ground-line of the adjacent soil, to ensure uniformity of temperature; and the cisterns should always be at the end opposite to the kiln in a single-floor house, and in a two-floor house at the kiln end, so that labour may be saved. They should invariably be so placed that the entire control of the temperature of the steep-liquor can be secured, as temperature has great influence in starting growth, and so arranged that corn can be readily screened into them when filled with water so as to enable the thin corn and refuse to float off. The water must also have command of them, so that it can be run in from

Fig. 1.



below and overflow at top prior to a change of steep-liquor, or at any time during the continuance of steeping. The construction of the cisterns, as seen at Fig. 1, should be such that the disagreeable labour of emptying by shovels should be

obviated, for the grain is quite capable of running down to the growing-floor if the cisterns are rightly made and placed. Their capacity should invariably be ample to steep the utmost quantity of corn the floor can possibly grow in the coldest weather.

The growing-floor may be of many materials, for quite a diversity of floors are used—probably tiles are most esteemed; then cement concrete worked to a good face; brick; clunch, or a mixture of chalk and gravel rammed to a hard level surface; York stone set in cement; iron tiles; and wood. The idea has occurred to many to have a double floor, with the upper one of some porous material, perforated so that ready circulation of air may be secured, and a discharge of the carbonic acid gas generated by germination. It is now being worked or successfully experimented upon in several places. This question alone is of great interest and importance.

The capacity of the growing-floor is the true gauge of the power of the malt-house, and every measurement of other parts should be calculated solely upon such capacity. A 15-quarters house, such as we are now considering, should never have less superficial area of combined couch and floor-room than 2600 feet if in the south of England, or 2400 feet in the north of England or Scotland, unless any exceptional condition of altitude or position affect the mean annual temperature of the floor, when the skill and knowledge of the engineer would regulate the areas by such information and data as he could secure or observe. It cannot be too often impressed upon all connected with malting in any way, that one of the prime factors in making good malt is heat, and the manner in which it is communicated to or absorbed from grain. Throughout the whole of those portions of the process we have been following thus far, it is always most important to secure a right supply of cool moist air to the corn in steep, couch, or for the first seven to ten or more days of its growth on floor. In small maltings this can only be done by regulation of doors, windows, and shutters; and the same means are used also to assist in the regulation of temperature. In fact, these agencies, coupled with the shovel and the particular construction of the house, are the only ones employed in the vast majority of maltings of all sizes, to regulate or control the two chief conditions of malt-making.

The kiln or drying-house is a building in which the conditions are of an exactly opposite character to those we have been considering. Heated air is called upon to dissipate and remove so much of the moisture as can practically be removed

from malt, to utterly stop growth, and at the same time to impart characteristic flavours and influences which concern the brewer chiefly, but of which the engineer should have sufficient knowledge to enable him to guard against the errors to be witnessed in so many places. The kiln should ever be a lofty and roomy structure of brick, with a high roof surmounted by a cowl. Its area of drying-floor should never exceed one-fourth or be less than one-sixth of the growing-floor, nor should the combined air inlets and discharges ever bear a ratio to each other exceeding that of four to five. Inattention to, or ignorance of this simple rule on the part of many kiln-builders has caused an enormous waste of fuel and damaged immense quantities of malt. The mode of construction of furnaces of kilns may vary widely, and upon the form depends the area of grate-surface. The drying-floors should be two in number placed at a suitable distance apart. The lower floor should have its distance from the furnace regulated by the construction of the house and the nature of the malt desired to be produced. In altering old kilns the author has had opportunities of trying all heights ranging from 5 feet 6 inches to 27 feet. In new kilns the right limits are from 12 feet to 18 feet, somewhat ruled by utilisation of the kiln as a malt store. No fixed rule for the regulation of this height has yet been formulated. The first malt-kiln with two floors that was successfully worked in this country was one altered by the author three years ago.

In the great majority of malt-houses, especially of the size we are now more particularly considering, the height of the floor above the furnace is inconsiderable, and it has been the custom to load or throw in the malt with a shovel. When the height is increased, and another floor is also added, it is rarely possible to continue this practice, and the green malt has to be hauled up in baskets by some simple form of windlass. After the kiln is loaded, several of the main characteristics of the malt are entirely dependent upon the temperature and volume of the current of ascending air. It may seem incredible, yet it is a fact, that there are hundreds, if not thousands, of maltings working in which no thermometer is employed to ascertain the temperature of either air or corn; and no one but the author seems ever to have tried to ascertain the volume of air passing up any particular malt-kiln, or to calculate the hygrometric condition of the air upon its ingress and egress. Nor until very recently has any attention whatever been paid to the differences of temperature to be found in the malt when drying upon nearly all kilns, although due consideration of the

facts taught by such ranges of temperature as can be constantly found in kilns of all conditions and sizes would lead one to suppose that any maltster who had but once had his attention directed to this subject would no longer allow such dangerous extremes of temperature as are almost invariably found to exist. Kilns that work with two drying-floors possess several advantages, of which probably the chief are the regularity of temperature upon both floors, and the economy of fuel and labour. As, however, we have in this country at present only some dozen kilns with two floors of so small a capacity as 15 quarters, we will leave fuller discussion of this subject until we consider much larger houses. Many materials are used for the drying-floors of kilns. That which is undoubtedly the best is Hermann's patent wire, although, in so simple a question even as that, there is still plenty for engineers to do to overcome hydra-headed prejudice upon the point of the different descriptions of floor which are all called good by users. There are earthen tiles of several makes, cast-iron tiles, perforated sheet iron, woven wire, and woven horse-hair. The Hermann wire forms a singularly strong and level floor, which permits of the greatest area possible for the free passage of ascending heated air. It is very durable, and incapable of getting out of repair, and never damages the most tender or friable malt by inequalities of surface. The chief objection to woven wire is its comparative frailty. It is very largely used, and is much liked by some. Earthen tiles are liked by many eminent maltsters and others, chiefly because they are supposed to be capable of regulating the temperature of the air which follows the intensity or dulness of the fire. The tiles naturally absorb and give out heat relatively to these changes. One objection to their use is the small free area of holes, and the wide margins entirely free from the passage of air. In nearly all cases they are roughly fixed, so that, when shovelling green malt upon them, many kernels are broken or damaged. Of iron tiles still more may be said, as they possess nearly all the defects already set forth, without the one imaginary advantage. Their sole merit is that they do not break readily.

In maltings of two stories, the upper one is almost invariably used to store corn, malt being customarily placed at the kiln end, and barley over the cisterns. This floor is very frequently divided into a series of three or more compartments, so that the operations of screening and sorting barley, or malt, can be conducted separately, and the commingling the dust set in motion by screens is avoided. In

buildings of three stories it is not unusual for the first floor to be used for storage, and the ground and second floors for growing and withering. The reasons for this arrangement in small maltings are good and varied, i. e. less height to lift or carry barley, greater ease and facility of discharging malt from kiln at lower level, one lift only of green malt or steeped barley, disposal of the greatest weight (stored grain) at a lower level, and power to store malt in an air-tight chamber, &c. Owing to the miscalculations of engineers or architects, it is by no means an uncommon thing for the stored grain to carry away floors incapable of sustaining it. The average 15-quarters malting consists, then, of one building for receiving, steeping, growing, and storing grain and malt; and another building devoted to the drying of malt or barley, and sometimes to the storage of malt and fuel. Apparently, few things could be simpler.

Section II.—Implements.

The machinery, implements, and instruments used in such a building are so few and simple that they can be rapidly enumerated as follows:—

A pump (almost invariably).
Water-can and hose.
Shovels of tinned iron or steel, and wood.
Plough of wood or iron.
Some description of barley-screen.
A malt-screen.
Weighing-machines.
Bushel measures.
Thermometers.
Fire-irons and brooms.

So well are all these things known that it is needless to describe them. Nothing remains to be added to them but sacks and a cat, and the whole equipment of, not only a 15-quarters, but many much larger malt-houses is enumerated.

A 30-quarters house so closely resembles the typical one described, that the only difference is, it takes two men to work it instead of one, and it would be much more likely to contain a windlass and baskets for raising green malt to the kiln.

A 50-or 60-quarters house requires three or four men, according to the system upon which it is worked. There are several slight differences of working houses adopted in this country, which go under the names of the places in which they originate or are most practised, or of their inventors—such

as Galland's, Marbeau's, the Ware, Newark, Burton, Essex, Scotch, &c. These variations are chiefly interesting to maltsters, and consist of differences in duration of steep, sprinkling on floor, growth of acrospire (or plumule), extent of withering, duration and extent of drying, &c.

A 75-quarters house is the largest that can be worked upon the English system unless there are three growing-floors, although some of much greater size are working with results that are supposed to be satisfactory. The capacity of such a house is 5000 quarters per season. The proper area for growing-floor for 75 quarters every three and a half days is not less than 12,000 feet, and in a house with two floors it follows that both must be 120 feet by 50 feet.

Any malt-house with floors working upon this system of greater breadth than 50 feet labours under defects which ere long will be considered fatal, for it is difficult, if not impossible, rightly to regulate the temperature of the corn or the access of fresh air. There are also structural difficulties which become serious defects in those cases where imperfect or erroneous calculations have been made of the strain when such a house is fully laden. The curious facts connected with the pressure of grain in bins, carefully experimented upon by Mr. Roberts, and given to the world by his paper read at the Southampton meeting of the British Association* in 1882, require to be carefully studied in building such large malt-stores as must necessarily be attached to maltings of large size. Indeed, the whole question of malt storage in bulk, apart from the consideration of the construction of the store as generally understood, is one which will well repay the careful study of the engineer.

The general arrangements of a 75-quarters house are very similar to those already described, with such differences as must be made to suit the conditions of the work, the necessity for adapting such machinery as the intelligence of the maltster permits him to adopt, and the increased size of the corn and malt stores needed. These generally necessitate the erection of an additional building exclusively devoted to malt storage.

The steeping-cisterns (Fig. 1, p. 71) must be two in number, and are best placed at the kiln end of the house in such a position that they project above the first floor two or three feet. ...ould be of iron, conical in form, and provided with ... large, full clear-way, to permit of the discharge of

* "...ressure of Wheat stored in Elongated Cells or Bins," by ISAAC ...S.

steeped corn by gravitation, and ought to have an overflow, and a number of inlet and outlet pipes all fitted with strainers. They should possess, in addition, a series of perforated pipes, by means of which water can be sprayed or sparged over the corn, like a shower, upon the whole surface in equal volumes. Several valves are used for discharging cisterns, but none seems so simple as that designed by the author.

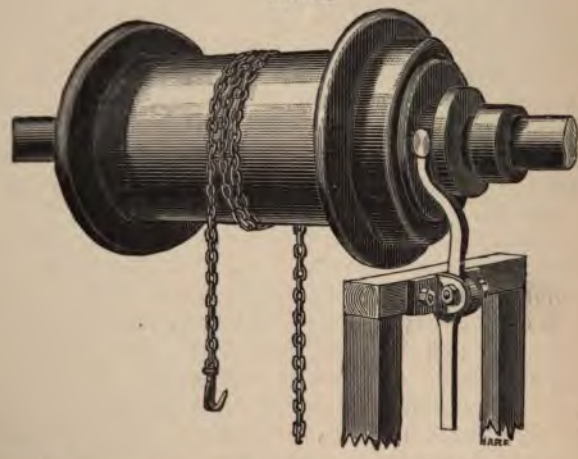
For a big malting a storage cistern or tank should also be used, of sufficient capacity to equal two steeps, at a proper altitude to command the cisterns and growing-floors for sprinkling and washing down. If a separate engine and boiler house is built, such a tank conveniently forms its roof.

The kiln should have double floors, each of an area of at least 1600 feet; and as to make such a building square is not always practicable or desirable, it may be built of greater length than width, and be provided with two fireplaces or furnaces. It should always be used as a malt store also, for if properly designed, it furnishes good storage for 1200 to 1500 quarters of malt.

The diversity of tools and appliances falling under the second section is much greater than in a small house, viz. a steam boiler and engine (or gas-engine), with main and counter shafting, and frictional hoists, elevators and conveyors, screens, sorters, cleaners and weighing machines. Formidable as this list looks, the power required is very small. A steam-boiler of 6 horsepower, and an engine of 4 horsepower nominal, is ample to do all, and in rare cases it may be preferable to fix a 3½-horsepower gas-engine. When a gas-engine is used, care must be taken to devise some simple method for regulating the temperature of the water used in severe weather, as with a steam-engine the exhaust steam can be economically utilised for this purpose. The arrangement of the shafting naturally varies, and it is unnecessary to describe it. It is frequently desirable to attach to it, at one or more places, barrel drums loosely fitted between collars, and a frictional clutch as shown at Fig. 2, which with a simple lever can be made to grip the barrel tightly and raise sacks, &c., to any floor, or can also lower any ordinary weight as desired. In addition to this mode of raising barley to the loft, it is always desirable to have a small receiving-hopper placed on the ground floor, into which the barley can be weighed immediately it is received from the waggon or truck; and, passing through a criddle screen, it can fall into a vertical elevator consisting of buckets attached to a chain or belt in the ordinary way. The head of the elevator should be at the

top of the building, and so arranged that the barley can be at once discharged into the screen and sorters or into bins. The removal of the barley horizontally from point to point is best effected upon a wide linen or indiarubber belt, as no injury can possibly be done to the corn. In all cases where it is practicable a conveyor of this class is the best possible way yet invented for loading kilns with green malt; and as such malt will run up an incline of forty degrees, it might be much more largely adopted than at present. In this country, barley

FIG. 2.



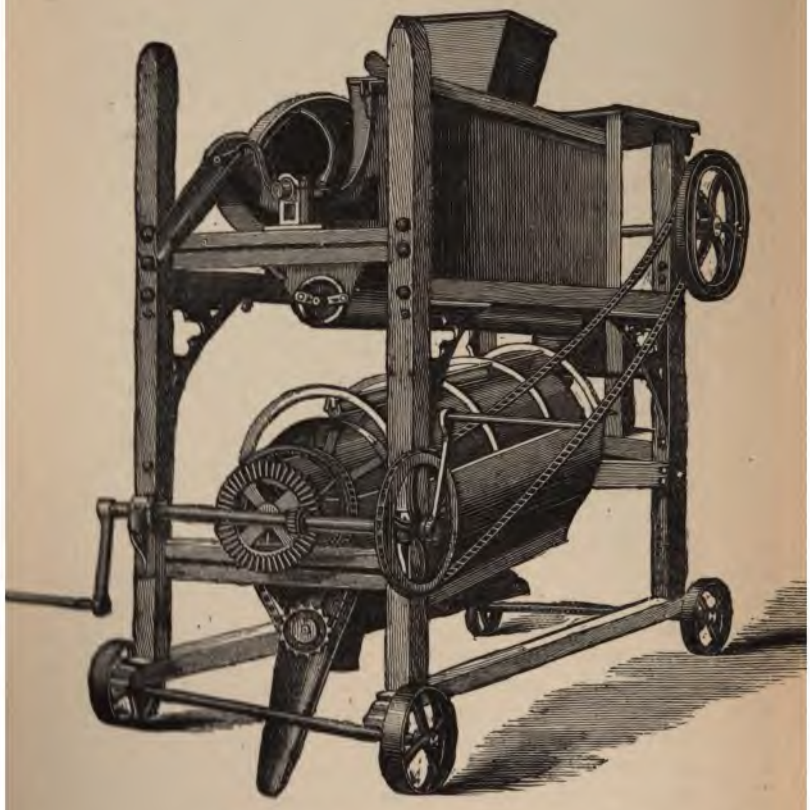
is generally screened once only before steeping, by passing it through a Boby's or Penney's screen. Much greater attention is paid to the subject abroad, and it is rightly held to be of much importance thoroughly to clean, sort, and sweat barley before use. A few men of enlightened ideas in this country think so likewise; and here again we have a sphere of much usefulness marked out for the engineer.

In screening barley it is important to remove from it all dirt and foreign elements of every kind, all undeveloped or imperfect barley-corns, and frequently to divide the large, full, plump corn from the small, lean, hungry kernels, which nevertheless have the power to make fairly good malt if properly managed. It seems absurd to have to say that such difference of character in corn necessitates a difference in treatment, yet so many good men act in blissful ignorance of this self-evident [illegible] it is necessary to give it as the reason for the employ- [illegible] roper sorting machinery. Large, small, over-ripe,

undeveloped, and damaged kernels, of any species of grain, must germinate differently when subject to precisely the same conditions of air, humidity, and heat for like periods of time. Further than this, all barley, no matter what its condition or the country in which it grew, has almost invariably adhering to it the germs of such low organisms as necessarily exert a baneful influence first upon the malt, and afterwards upon the resulting beer, unless removed by vigorous brushing and washing prior to steeping. To invent and adjust the machinery needed to perform these operations in the best and simplest way, is necessary and good work. Several Continental machinists now make screens that separate from barley all other seeds or grains, dirt, refuse matter, broken and damaged kernels, and finally give three, four, or five different grades of corn from sample, the grading being ruled by size of each individual kernel. In Van Gelder and Apsimon's machine for instance (see Fig. 3) a small conical barrel of wire mesh of suitable size, admits of the passing through it of all barleycorns, but rejects all larger than barley. The corn thus freed then falls into a second barrel, of greater length and diameter, which has fitted to it an internal worm for the right distribution of corn, and a fan to blow out all floating dust. The barrel is covered with woven wire of varying mesh, which makes the following grades:—I. Dust, dirt, chaff, &c., absolute refuse. II. Thin, refuse, and tail-corn, fit only for poultry feeding, or grinding. III. Larger tail-corn, suitable for the same purposes, or, under some circumstances, useful for steeping. IV. and V. Two other grades of malting-corn. VI. Prime, big, plump corn. Each and all of these grades of malting can then pass separately through a third cylinder of sheet iron or zinc, furnished with a series of indentations of differing size, in which, as the barrel rotates, spherical seeds of the same diameter as the particular grade of barley, half-corns, or kernels, crushed and otherwise imperfect, can rest. The slowly rotating barrel carries all these things to a higher altitude than perfect corn, which falls back below a shelf fixed at a particular angle (usually thirty to thirty-five degrees), and passes out at the end almost free from imperfection. The refuse is carried above the level of the shelf, and consequently falls upon it, and, by means of a small screw or any similar contrivance, is likewise conveyed into a proper receiver. Great varieties of such machines are made by Seck, Ainé, Pernollet, Schwalbe, and many others. Their work is excellent, but at present they all labour under the serious defect of tedious slowness. Other useful screens are made by good makers,

consisting of flat sheets or trays of metal, perforated in a diversity of ways with holes of varied size and form, to all of which a reciprocating or shaking motion is given. There is,

FIG. 3.



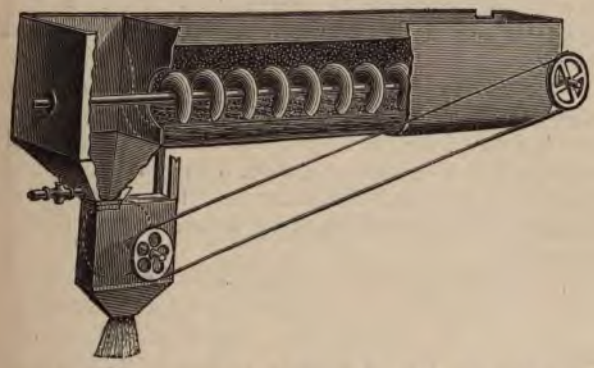
however, room for much more improvement and scope for invention here.

After passing through all this treatment, corn is still unfit for steeping, for mould spores, dust, and a diversity of organic imperfections that adhere to grain still require to be removed. Several brushing, polishing, and washing machines have been d to do this. That used by M. Galland, at Maxeville, n at Fig. 4 is simple, ingenious, and effective. Barley 'nto a cylinder, in which is fitted an ordinary Archi-

medean screw or conveyor, rotating at a fair speed. A current of water flows in the opposite direction to the screw. This, combined with the agitation and friction imparted by the motion of the screw, finally frees the barley from its remaining imperfections, and it passes with the liquor into the steeping-cistern.

Two weighing-machines at least should be fixed in each malting. One should be placed so that it can conveniently weigh every bushel of barley received into the building, and

Fig. 4.



the other to weigh accurately all malt sent out. Several automatic machines are good, and sufficiently well known to need no description. It is generally preferable to select those that act against a counterpoise equivalent to each charge, rather than one depending upon a spring or factors of a small weight, as, should any defect arise from wear or any cause, the error is kept within small bounds.

Class B.—Pneumatic Malting.

We pass now to the second division of our subject, Pneumatic Malting, which may be freely interpreted to mean malting by a process in which the functions of air are intelligently utilised in germinating grain. The value of many good things may be measured by the duration and intensity of their struggle against prejudice and interest. The fight against these twin giants, on behalf of new systems of making malt, was bravely started by Stead in 1842, and was continued later on by Tizard, who may justly be called the Father of Pneumatic Malting. To them followed Galland, whose name must be linked with this system of malting for many generations with all honour and respect.

The great principles already enunciated are all capable of application to malting conducted upon this plan, many of them with greater force and intensity.

The construction of any pneumatic malting varies greatly from that we have been hitherto considering. Indeed, everything is changed. Barley stores must be much larger, for malting goes on winter and summer alike, but barley is chiefly bought in autumn and winter, so the summer stock must be sweated and laid in. The stores must also be accessible from the kiln, for no man who has intelligence enough to make such a house would steep unsweated grain at any time. If the house is moderately large it must have double kilns, or at least four equally good drying-floors. The malt-stores may be very much smaller; for who, comprehending the subject, would use malt over three months old? Greatest change of all, no space whatever is needed for growing-floors, as all the germinating is best conducted on the basement floor, below the stores and kilns. Consequently, a pneumatic malting need not occupy more than 35 per cent. of the area occupied by an ordinary malting of the same capacity.

The number of pneumatic maltings actually existing in Great Britain is only four, but several are in course of erection. The number abroad is considerable, some of them of great size. The one at Troyes already referred to, is capable of making as much malt as ten 75-quarter houses in this country. This building is shown in transverse and longitudinal section at Figs. 5 and 6, and in plan at Fig. 7 of the engravings. In these figures, A indicates the germinating-cases. B, Saladin's patent turning-screws. C, *a*, air-channels. D, passages. E, E, main driving-shafts and pulleys. F, metal recesses to fit turning-screws. G, elevators. H, trap-doors. I, air-channels. J, openings to growing-floor for air. K, S, engines and fan room. L, N, fans, supply and exhaust. T, boiler. W, chimney. [illegible] well. The whole space occupied is the area necessary for kilns, malt and barley stores, engine and boiler house, and fans. No additional area is required for germinating-floors, as ten germinating-cases A are placed in the basement below kiln and stores. The building is of brick, the internal walls above [illegible] the ground-line resting upon cast-iron columns and rolled-iron [illegible] joists. The germinating-cases A, A are of iron; the bottoms [illegible] are double. These plates admit of draining the corn, if the [illegible] case is also used as a steeping-cistern. Their chief [illegible] is to admit of ready circulation of the air [illegible] to be described. Large channels *a* serve as [illegible] et, and to convey the air to or from the

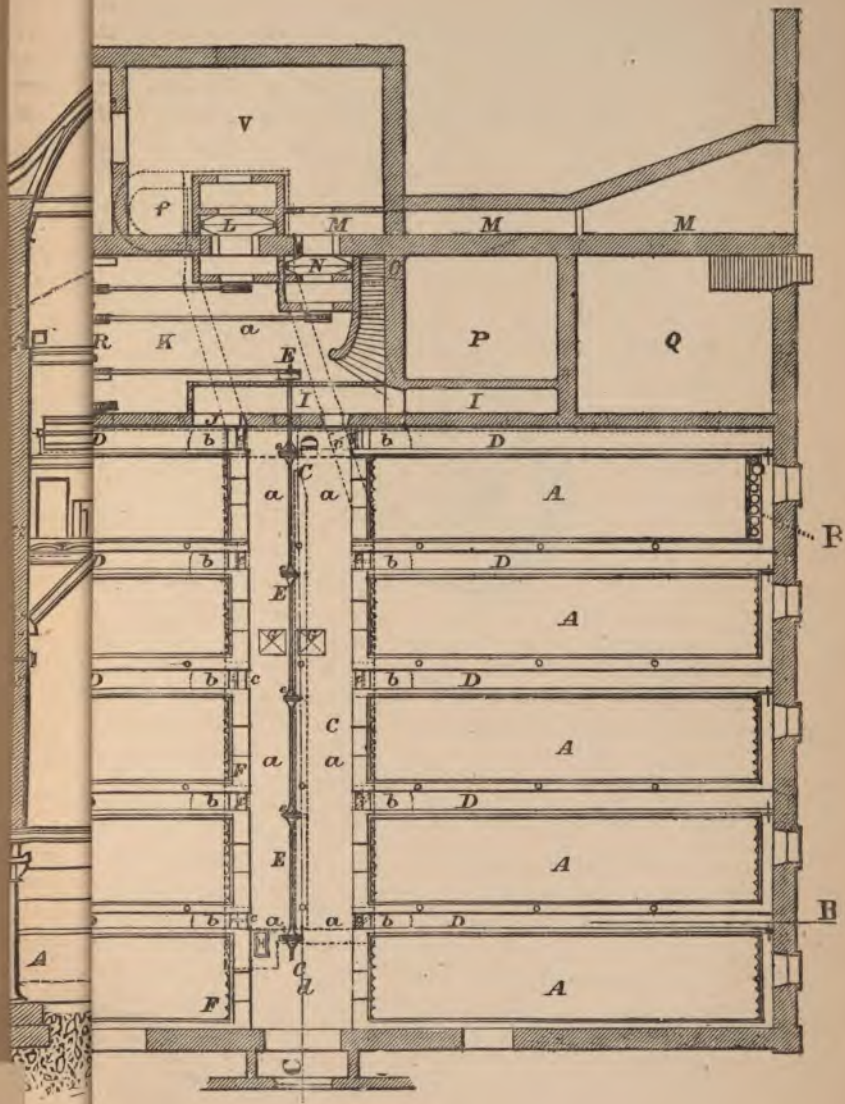


Fig. 7.

The great principles already enunciated are all capable of application to malting conducted upon this plan, many of them with greater force and intensity.

The construction of any pneumatic malting varies greatly from that we have been hitherto considering. Indeed, everything is changed. Barley stores must be much larger, for malting goes on winter and summer alike, but barley is chiefly bought in autumn and winter, so the summer stock must be sweated and laid in. The stores must also be accessible from the kiln, for no man who has intelligence enough to make such a house would steep unsweated grain at any time. If the house is moderately large it must have double kilns, or at least four equally good drying-floors. The malt-stores may be very much smaller; for who, comprehending the subject, would use malt over three months old? Greatest change of all, no space whatever is needed for growing-floors, as all the germinating is best conducted on the basement floor, below the stores and kilns. Consequently, a pneumatic malting need not occupy more than 25 per cent. of the area occupied by an ordinary malting of the same capacity.

The number of pneumatic maltings actually existing in Great Britain is only four, but several are in course of erection. The number abroad is considerable, some of them of great size. The one at Troyes already referred to, is capable of making as much malt as ten 75-quarter houses in this country. This building is shown in transverse and longitudinal section at Figs. 5 and 6, and in plan at Fig. 7 of the engravings. In these figures, A indicates the germinating-cases. B, Saladin's patent turning-screws. C, *a*, air-channels. D, passages. E, R, main driving-shafts and pulleys. F, metal recesses to fit turning-screws. G, elevators. H, trap-doors. I, air-channels. J, openings to growing-floor for air. K, S, engines and fan room. L, N, fans, supply and exhaust. T, boiler. W, chimney. *f*, well. The whole space occupied is the area necessary for kilns, malt and barley stores, engine and boiler house, and fans. No additional area is required for germinating-floors, as ten germinating-cases A are placed in the basement below kiln and stores. The building is of brick, the internal walls above the ground-line resting upon cast-iron columns and rolled-iron joists. The germinating-cases A, A are of iron; the bottoms are double. These plates admit of draining the corn, if the germinating-case is also used as a steeping-cistern. Their chief object, however, is to admit of ready circulation of the air by the means to be described. Large channels *a* serve as drains for moisture, and to convey the air to or from the

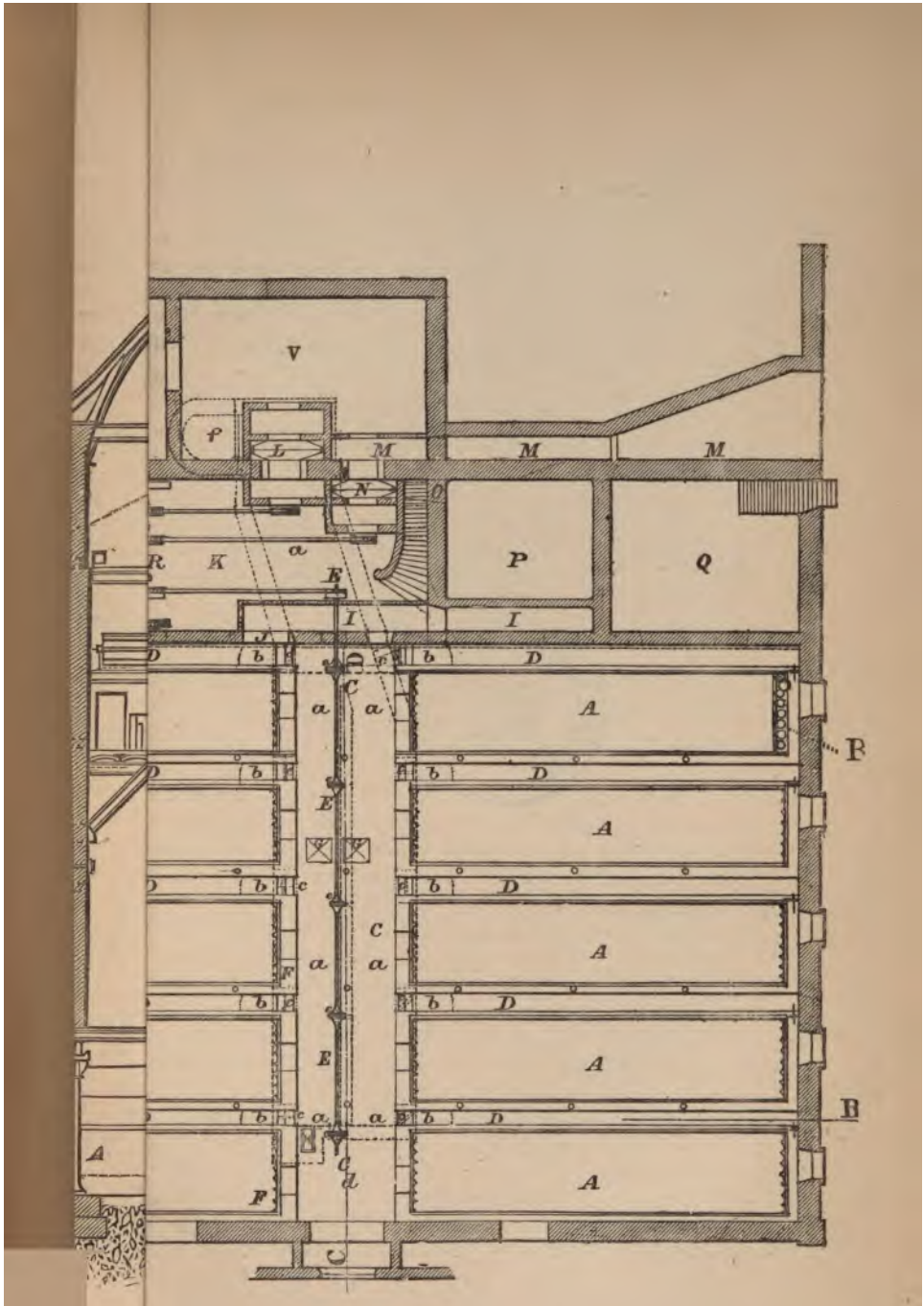
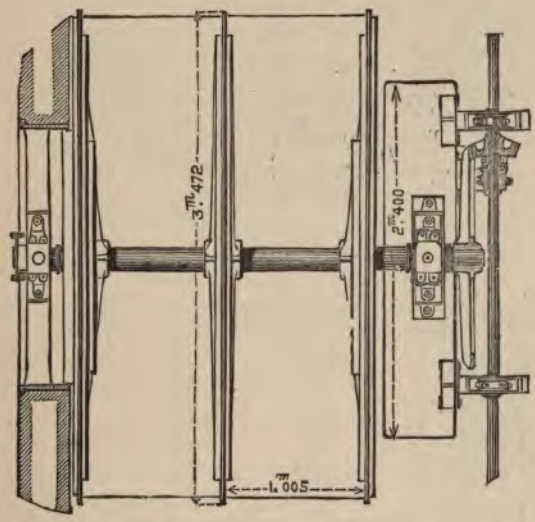


Fig. 7.

THE ASTOR LIBRARY
NY

growing corn. Between each case is a passage D enabling the maltster to have free access to the corn at all points. With the exception of the driving-shaft E, all the machinery is in duplicate, so that the possibility is remote of any breakdown that would seriously affect the working of the house. This is necessary, as should the fans L, N be stopped for twenty-four hours, the corn germinating at a depth exceeding 30 inches would inevitably heat and be spoiled. The boiler T and engines S are of the common type of 20 horsepower nominal. The fans L, N are the Farcot patent. The lower floors of the kilns are provided with the Schlemmer patent mechanical turners. The turners in the germinating-cases are Saladin's patent.

FIG. 8.



The germination of the grain is effected by cool, moist air, after passing through the cooler and moistener known as an "échangeur," and which is illustrated in Figs. 8, 9 and 10. As the germinating grain has a depth of from 30 to 40 inches, some pressure is required, and mechanical means are necessary for efficient and economical turning. The échangeur is a very ingenious utilisation of the well-known rapidity of evaporation of any liquid when spread out in very thin layers over large surfaces and exposed to a current of air. It consists of a cylinder, or series of cylinders, of increasing diameter, placed

FIG. 9.

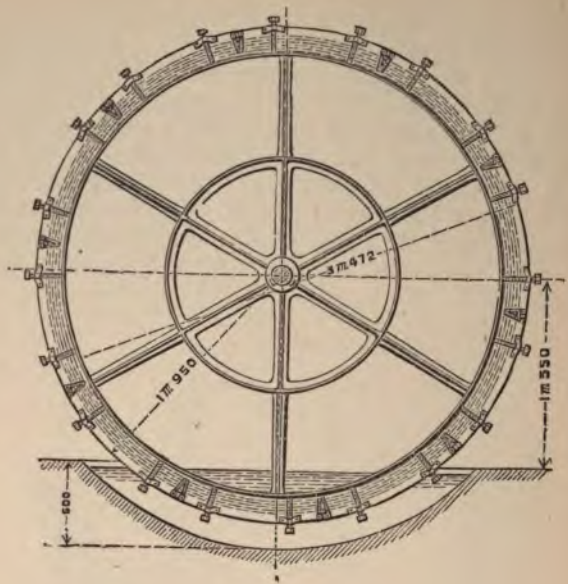
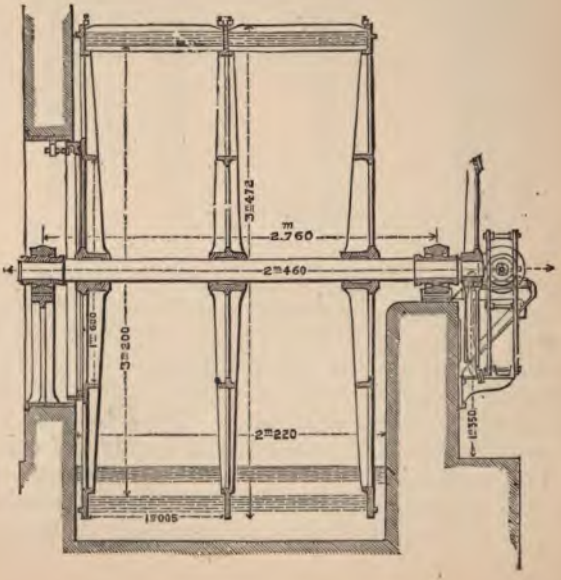

3m472
1m950
1m550
500

FIG. 10.


3m472
2m760
2m460
1m600
3m200
2m220
1m350
1m005

one within another. Each consists of finely perforated sheet-iron. They are placed in a trough of water, just sufficiently immersed to ensure complete wetting. When rotated at a slow speed, the surfaces of all the cylinders are kept just wetted. A volume of air is either driven or drawn through, as may be required, for any particular purpose. The air in its passage comes first into contact with the moistened cylinders, and if hot and dry, it becomes moist and cool, for the constant evaporation upon the cylinders has a very considerable refrigerating effect. This was well known to the Egyptians over four thousand years ago, and the porous bottle, or "gargouleh," of Esneh, has been made until the present day to keep the drinking-water of that hot country cool and fresh. The échangeur is like a gigantic gargouleh, and by increasing the size and number of the cylinders, and causing the water in the moistening-trough to circulate, any volume of air can be wetted to the saturation limit corresponding to its temperature, and reduced to the actual temperature of the water or glycerine used. It will be seen that this apparatus gives the maltster complete control of the humidity and heat, as well as volume, of the air driven through germinating corn.

The Saladin turning apparatus consists of a cylindrical frame provided with rollers which run on rails at the edge of the germinating-cases. This apparatus is illustrated at Fig. 11. It is carried to and fro from either end of the case by compensating rope gearing, which at the same time gives motion to the turning-screws. These screws do not quite touch the bottom of the germinating-case, but just skim it. The cases are generally made wide enough for six turners.

The kilns are double, each possessing two floors. The construction of the furnaces is of the ordinary French pattern. The arrangement of the house permits of great regularity of working. Every day 130 quarters of barley are screened, sorted, cleaned, and passed into a steeping-cistern. When sufficiently steeped it runs through piping into the germinating-case which in the natural order of working happens to be empty. Here it forms the couch, i. e. the heaping of damp corn to gain heat. When it is desirable to open couch, or prevent further accession of heat, a small amount of air is forced through the grain by opening the trap-door connected with the main air-channel. This furnishes the growing corn with oxygen, removes the carbonic acid gas, and regulates temperature of the mass of grain. Later, the Saladin turner is put in motion for a few minutes about every eight to twelve hours. The screws in rotating upon their axes are slowly propelled horizontally. They

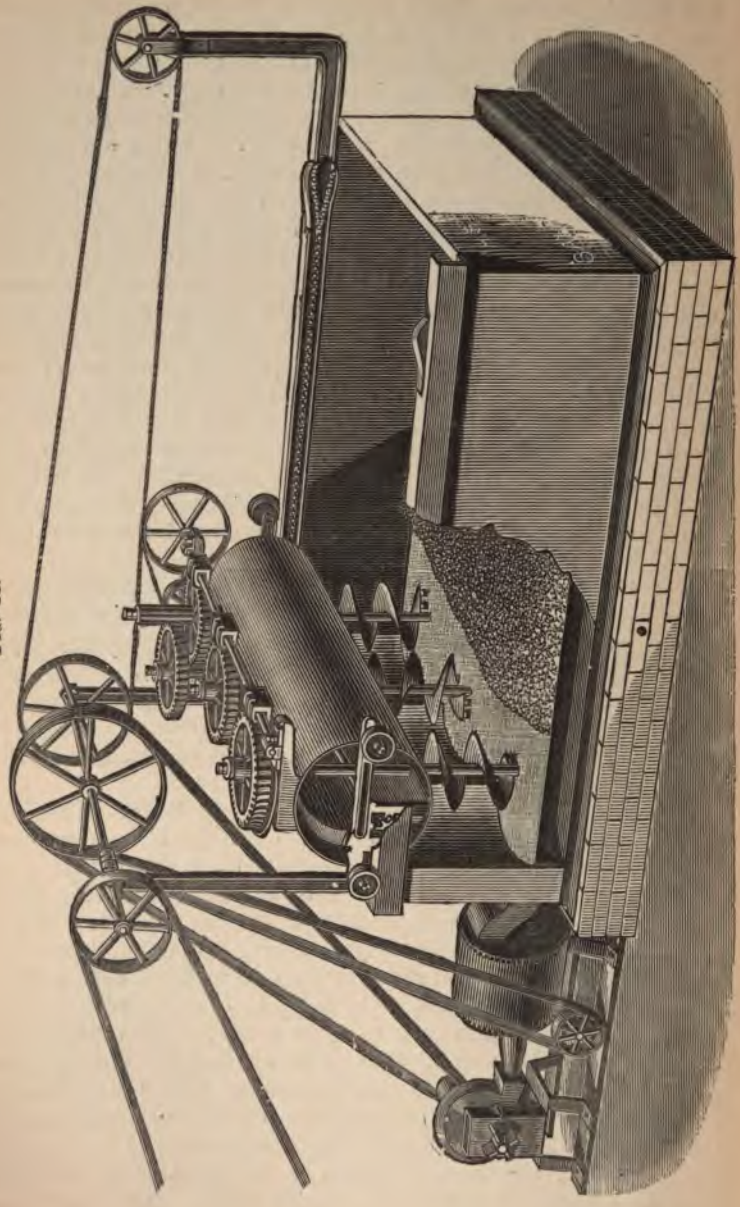


FIG. 11.

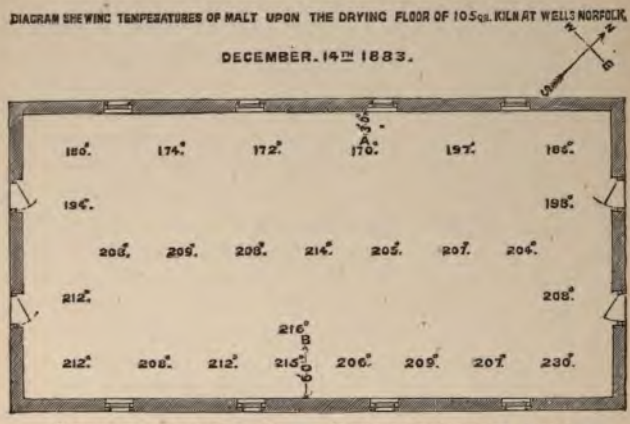
thus effectually turn the grain, and leave it perfectly smooth. This turning process prevents matting of the roots, the regulation of temperature and exposure to air being effected by means of the cold air from the "échangeur." When the grain is sufficiently grown, it is elevated to the kiln. For forty hours it remains upon the top floor, it is then dropped upon the bottom floor, a further charge of green corn following upon the top floor. The benefit is mutual. The bottom is maintained at an even temperature, for it is virtually plunged in an air-bath, and as free radiation of heat is prevented, the top surface of the malt is necessarily nearly as warm as that next the wires, which in its turn is subject to lower heats than would be necessary if free radiation from the surface were allowed. The top floor, by the intervention of the layer of malt between it and the fire, is prevented from coming into direct contact with heat of a dangerous and damaging degree. The same heat which is used to dry one floor, and in an ordinary kiln passes at once into the air as waste, is the best possible description of heat, namely very slightly moistened heated air, to remove the moisture from the second layer of malt at a low temperature. It is of vital importance to retain this green malt at a low heat as long as any degree of moisture exceeding say 15 per cent. is retained by the corn. The differences of heat between an ordinary kiln and a Stopes double kiln are best seen in Figs. 12 and 13.

The degree of heat upon the kiln and the duration of particular temperatures rule very largely the percentage of dextrine produced by the malt, as well as the colour of the resulting wort. A final distinct advantage is the total abolition of turning the drying grain, not only economising the labour, but avoiding the positive injury to dry malt of placing it above that which is damp, through the absorption of a portion of the moisture. All the screens, sorters, and other apparatus already described are employed in maltings of this class. The chief difference is that in our English maltings it is the exception to find them, whilst in pneumatic houses it is unusual for them to be absent.

The advantages of the Saladin system over that hitherto working in Britain are numerous, the one disadvantage being the employment of much more power. The area occupied by the building does not equal one-third of that otherwise required. The actual growing-floor space is only about one-seventh, and the number of workmen (ruled necessarily by the size of the house) is reduced two-thirds. The use of plant and premises is continuous, the process of malting being equally well performed during the summer months. The further advantage

of this is that brewers secure entire uniformity in age of malt, while by the English system the stock of finished malt necessarily fluctuates largely. All growing corn is subjected to the same conditions of surrounding air, exposure, and temperature.

FIG. 12.



A. SUPPOSED COLDEST POINT. ÷ B. SUPPOSED HOTTEST POINT.

FIG. 13.

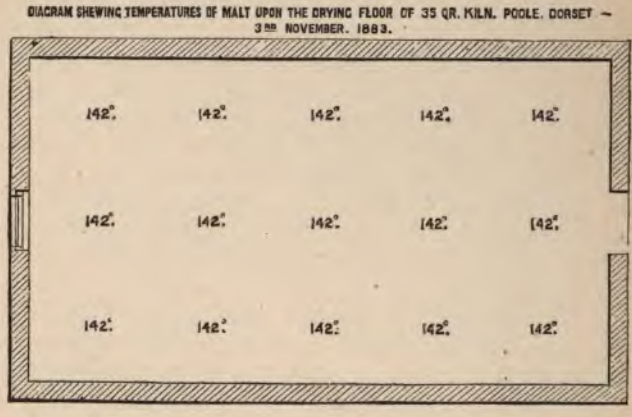


DIAGRAM SHEWING TEMPERATURES OF MALT UPON THE DRYING FLOOR OF 35 QR. KILN. POOLE. DORSET —
3RD NOVEMBER. 1883.
142° 142° 142° 142° 142°
142° 142° 142° 142° 142°
142° 142° 142° 142° 142°

The volume of air supplied to the germinating corn is entirely under control, as are also its temperature and humidity. When germination is arrested and the green malt is drying, the double kilns ensure control of the temperature of the corn in the kilns.

The infrequency of turning the germinating grain benefits the growth of the roots and the development of the plumule, besides saving much labour. No grains are crushed or damaged by the feet or shovels of the workmen. The air supplied to the corn can be inexpensively freed from disease-germs and impurities. The capital needed for malting can be reduced by the diminished cost of installation, the reduced stocks of malt in hand, and wages paid. The quality of the malt made is considerably improved. The percentage of acidity is much reduced, the stability of the beer is increased, and a greater percentage of the extractive matter of the barley is obtainable by the brewer or other user of the malt. These advantages must eventually be recognised.

Class C.—The Manufacture of Black, Amber, Crystal, and Other Special Malts.

Hitherto we have been considering one class of malt only, viz. that technically known as pale malt. Several other varieties exist. Under this heading we shall consider those only which depend upon the conditions already explained, but with a variation of the final process of drying, such variation being chiefly a comparatively slight difference of temperature.

Amber, porter, blown, or imperial malt can be made in any ordinary malting, the differences to which they owe their names being almost entirely effected upon the kiln. The scope they afford to the engineer for employment or improvement is infinitesimal. They deserve mention only for the impressive fact, that the difference in temperature which will convert pale malt into amber or imperial is actually less than is to be found in the vast majority of kilns, between the temperature of that pale malt lying upon the surface of the tiles or wire, and of the upper surface exposed to the air. There is probably no kiln in Great Britain having only a single floor in which this difference is less than 50°. Pale malt next the tiles will be at 200° Fahr., and upon the surface 150° or less; and malt heated to 240° would make amber or imperial malt.

Blown or porter malt has the further difference that considerable heat is applied with suddenness before it has become dried. It is well known that any given temperature over 100° Fahr. will give much more colour to malt if still moist than a much greater heat if dry. Blown malt is exposed to the flare of fast-burning oak faggots or billet wood, and gains much colour and increase of size in consequence. Its use is an absurdity that is dying out, for the colour and flavour so gained are found to be very costly.

Crystal malt is green malt not fully grown, taken straight from the floor, and placed in a woven wire cylinder over a fire, and rotated. The curious sweetness of crystal malt to the palate may be readily accounted for by the mode of its drying. Sufficient moisture is present at considerable temperature to enable the diastase to convert a portion of the starch into sugar.

Black or patent malt is pale or other malt dried in the ordinary way, and then placed in a cylinder over a fire, and rotated. The starch and saccharine constituents are speedily caramelised, and a splendid deep colour is obtained, which is communicated to porter and stout. The chief difference in the appliances used in the manufacture of these (crystal and black) malts is the construction of the furnaces and cylinders. They have to be made in such a manner that free inspection of the malt can take place during roasting. They must also admit of ready lateral movement to facilitate filling and emptying; and appliances for proper cooling are of importance.

Class D.—The Gelatinisation Process.

Brewers' wort was originally produced by malting and infusing corn. Gradually it was found out that glucose, the chief ingredient of wort, could be produced by chemical and mechanical agencies from both grain and potatoes. Finally, it has been proved that the gelatinisation of grain produces results in some senses better than can be otherwise obtained, especially upon those grains, such as rice, which are known by analysis to be exceptionally useful in the production of beer, but which cannot be easily malted. No matter how much care may be given to the cleaning of barley, and purification of air and water, mould-spores and germs of other low organisms are always left. The conditions absolutely essential to the right growth of malt are also those most favourable to the reproduction of all such fungoid and other low organisms. The free use of antiseptics does not entirely overcome the difficulties naturally arising from such a state of things; consequently, malt, as we know it, must be always liable to this defect.

Gelatinisation effectually avoids this difficulty, for rice or any other grain which undergoes the high temperature and pressure of gelatinisation cannot have clinging to it a single vital spore or germ. By this process, which was invented and successfully established as an industry of importance by Messrs. Gillman and Spencer, nearly every condition we have been considering is nullified or removed. The engineer has the whole process in hand, and the maltster is set entirely on

one side. The construction of the building is unimportant. It is preferable to have lofty, solid, and specially arranged structures of several floors, but it is not imperative. Every necessary condition is entirely under the control of the apparatus and plant used. This plant consists of engines and high-pressure steam-boilers, steeping-tanks, gelatinisers capable of safely standing steam at high pressure, drying-kilns or cylinders, cleaning or sorting machinery, elevators, conveyors, and other minor tools that do not require recapitulation. Any engine will do, and the form of boiler is immaterial so long as it is able to generate steam at a pressure of four to six atmospheres. The steeping-tanks are of cast iron of ordinary form, provided with strainer-plates to admit of drainage. The gelatinisers are patented, and consist of cylindrical wrought-iron vessels duly fitted with steam-supply and exhaust cocks, together with filling and emptying valves and strainers. The kilns are also patented, and are both novel and effective. The furnace and encasing walls are of brick. The floors are of woven wire rotating over a series of drums, so that the moist corn is slowly fed from the top hopper, and, whilst being carried continually forward, is robbed of its moisture, and gradually exposed to as much heat as may be required. It finally reaches the bottom, and is discharged into the receiving-hopper, from whence it may be conveyed or elevated to any desired position for cleaning, sorting, and if necessary, grinding.

It will be noticed how very different such a process is from the ordinary methods of malting, and how completely it depends upon mechanical aid. As it is equally effective in nearly every way to the common mode of malting, and much superior in others, it will probably be largely used in a short time. The changes produced in rice by gelatinisation are indicated by the following analysis :—

——	Water.	Starch.	Dextrine Sugar.	Albuminates.		Cellulose.	Fat.	Ash.	Extractive matter.
				Soluble.	Insoluble.				
Raw rice ..	12·51	74·88	1·11	0·41	8·78	0·76	0·78	0·84	0·1
Gelatinised do.	9·63	77·2	2·96	0·13	8·62	0·33	0·43	0·7	0·1

The rupturing of starch granules by combined high temperature and pressure, and the essential empyreumatic flavours given by high kiln-drying in direct contact with the products of combustion, are not capable of tabulation. They, however,

constitute the chief value of the process. The points of superiority, in addition to those already enumerated, are its remarkable rapidity and certainty of action. Grain can be received, steeped, steamed, dried, and ground entirely ready for use in eight hours. Every kernel so treated is subject to precisely the same conditions of moisture, heat, and exposure, enabling the brewer to know accurately the composition of his wort—an element of uniformity impossible to attain in any malting belonging to classes A or C, and not absolutely attained in class B. All malt made in maltings A and B has invariably a large excess of (so-called) diastatic power. Gelatinised malt is deficient in this respect, but whenever used in conjunction with common malt, the excess of diastase present in the mash-tun is invariably sufficient rightly to convert the starch of the gelatinised corn. The high pressure and heats adopted during the processes of gelatinisation effectually rupture the granules of starch, making the constituent molecules enter freely into contact with the diastatic wort, which rapidly effects the change of starch into the maltose, dextrine, and numerous other like compounds that are essential in a wort intended to cultivate yeast plants. The peptonising influences of gelatinisation aid materially the formation of a wort duly containing the soluble albuminoids in that nice equilibrium so essential to healthful growth of yeast. Upon this growth the success of the brewer's operation so largely depends. The old belief in the superlative importance of fermentation has been freely questioned by a few for some time past. It is attributing causes to effects. Fermentations are controlled in the malt-house and mash-tun. The power to gelatinise such nitrogenous grain as rice, or starchy material as maize, adds immensely to the power of a brewer to control properly his fermentation. To the general public such control has the direct advantage of improving the quality of the beer produced. Rational cultivation of the yeast is invariably and absolutely an improvement of beer. To the engineer, gelatinisation of grain is of interest, as all its operations directly promote the development of machinery.

The production of germless maize-meal is, in several senses, malting, as the material is used in place of malt, after undergoing some of the processes of malting. It is successfully done by several makers and patentees—notably, Messrs. Tomkins, Courage, and Cracknall; Robertson; Muir; and Southby. Maize is degermed by special machinery, for in the germ are found the greater portion of the oils and fatty matters which preve[illegible] being liked. Maize has not yet been success-

fully germinated to produce pale malt; but very good black malt is made from it by Messrs. Plunkett, Dublin. The germless maize produced by Messrs. Tomkins & Co., after degermation, is dried upon kilns of special make at high temperature, thus securing some of the empyreumatic advantages that malt derives from kiln-drying. The kilns are patented by Messrs. Tomkins & Co., and differ from others in special firing arrangements of excellent character for such purposes as drying maize or corn. They simply heat air to any required degree; and as none of the products of combustion come into direct contact with the drying grain, any cheap or common fuel may be used. By their construction they also secure a very rapid upflow of air.

It has been the author's endeavour to point out the present sphere of usefulness of the engineer in malting, and indicate his future possibilities, without entering into special trade technicalities. Sufficient explanation of the processes enumerated has been given to interest those who like to acquire a general knowledge of any industries. There are many points which doubtless might profit from clearer explanation. Owing to the comparatively small degree of general interest in the whole trade, and the consequent poverty of literature relating to it, seeming trifles have been dwelt upon at considerable length.

The days in which malt drink was the staple if not universal beverage of young and old alike have gone by, to be followed by a time when such malt drinks as are consumed must be of great purity and fineness. Rough rule-of-thumb methods of preparation sufficed apparently formerly, but they suffice no longer. The scientist and the engineer have been called upon to supply a need. They have never been called upon fruitlessly in the past, nor will they be in the future; and doubtless they will raise the humble craft of malting to a distinct branch of science, and make in addition, a high and honourable calling of the Engineering of Malting.

DISCUSSION.

Mr. Perry F. Nursey said it appeared to him that the wire malt-kiln floor invented by Hermann was a very great improvement upon the ordinary wire floor. As he understood it, corns were liable to stick and get damaged in the ordinary wire-woven floor, whereas that did not happen in the Hermann floor. If he remembered rightly, Hermann's first floor was constructed with circular wires, but in that case, the grains

occasionally got wedged in the interstices. The inventor then superseded that floor by one constructed of wire more or less triangular in form, which gave a practically even surface, the spaces between the wires being insufficient to allow of any of the grains catching. If any of the points got in between, the grains immediately tipped over by their own gravity and fell level upon the floor. With regard to the échangeur he had had the pleasure of seeing it in operation on one occasion. It acted most perfectly as a thorough cooling medium, and he did not know whether to admire most its simplicity or its efficiency.

Mr. BARNS KINSEY said as Mr. Stopes had stated, and as most maltsters must be aware, there was a great difficulty in producing malt in Australia and Canada. He would, therefore, ask Mr. Stopes whether he had had any experience as to the effect of the pneumatic principle in those countries. A very large quantity of malt was sent into those countries from England. He knew that there was great difficulty in producing malt on account of the extremes of the Canadian seasons, and it appeared to him that the process which Mr. Stopes had described might have a very great effect upon the malt industry of Canada, and also assist to a great extent that of Australia. With regard to the process of Messrs. Tomkins, it had long seemed to him that that was the direction in which engineers should turn their attention, for the purpose of endeavouring to obtain some better method of drying than the very crude form of the open fire-basket. Engineers had great control over superheated steam, and why should they not control the temperature of the air and so bring it to the grain at precisely the temperature required in the different processes?

Mr. HITCH said that he did not think that Mr. Stopes could yet bring forward any proof of the pneumatic system having been brought to perfection in this country.

Mr. R. W. PERRY said that his father had used the pneumatic system successfully in Ireland for the last five years. They had never had a breakdown, and the system had worked perfectly.

Mr. HITCH asked what advantage Mr. Perry had found in the system.

Mr. PERRY replied that the advantages were absence of mould, cheapness of working, and economy of space in the building.

Mr. HITCH said that as far as making by the pneumatic process was concerned he had never had any experience, but

the samples of malt which he had seen as the products of that system had certainly been anything but perfect according to his idea. They had shown a very great amount of mould.

Mr. PERRY said the presence of mould was very often caused in the pneumatic system by the air not being sufficiently supplied, and that had brought the system into disrepute. But where the air was sufficiently continued there was very great freedom from mould.

Mr. E. G. HOOPER said it appeared to him that there must be an advantage in the pneumatic system if it could only be made simple enough; and he thought that what Mr. Stopes had recently done, in introducing the Saladin system, had gone far in that direction, especially in comparison with the Galland system. The arrangement for air-cooling, in other words, the "échangeur" brought out by Saladin, seemed to be a great improvement upon the old coke-towers of Galland. He believed that they would see, too, that the system of germinating in tanks was much more simple than the old arrangement of rotating drums which were used for this stage of the malting process. With reference to the kiln which Mr. Stopes had done so much to bring into use, he thought there was a very distinct advantage in it. In fact, it was an advantage which, as far as he knew, had never been disputed. In the first place it afforded a greater kiln space from the fact of there being two floors, and in the next place it was beyond question an advantage to dry off the greater portion of the moisture before the malt was brought into contact with high temperature. With reference to gelatinised grain, it was becoming a habit to speak about gelatinised grain and gelatinised malt, whether it it was rice, malt, or any other. He thought they should never lose sight of the fact that a gelatinised starch was not malt and never would be. The essential feature of malting was the production of diastase. Probably Mr. Stopes' reply on that point would be that malting brought about an alteration in the constituents, particularly the albuminoid constituents of grain, which had considerable effect in promoting healthy yeast growth; and that the gelatinising process also brought that about. But were they quite sure of their reasoning on this ground? It was a fact, he believed, within the experience of those who had used gelatinised rice and raw rice, that an equally good fermentation was obtained from raw rice as from that which had been gelatinised; and, if so, then the albuminous yeast aliment could not be a product of the gelatinising process. Of course it might be an advantage sometimes for trade purposes to call a gelatinised material a malt; but it should be always

clearly understood in those cases that though the material was called malt it was not therefore diastatic.

Mr. GILLMAN as the patentee of the gelatinisation process said that in one sense Mr. Hooper was right in taking exception to the term malt, if there was no diastase produced; and if diastase was an essential ingredient in malt. But there was no reason why the germination process should not be substituted by another process by which a diastatic power was produced. In this case it was substituted by gelatinisation by steam under high pressure and heat, which acted on the albuminoids and produced a diastatic energy. In other respects the process of manufacture was precisely the same as that of malting. The grain was steeped, it was gelatinised, and it was kiln-dried. In the other case it was steeped, it was germinated, and it was kiln-dried: gelatinised malt was therefore in every sense a malt. As to the change in the soluble albuminoids he might not have had so much experience of raw rice as Mr. Hooper, but the generally received opinion amongst brewers, and the statement in all the works on the subject, was that the yeast deteriorated through the use of raw grain. The experience which he had had showed that the yeast was strengthened instead of weakened by the use of gelatinised rice malt, showing that the albuminoids were rendered suitable for a yeast food. Those, of course, were matters which could be proved only by continual experience and working with the gelatinised malt.

Mr. INSKIPP said no doubt, as Mr. Stopes had remarked in his paper, prejudice had somewhat to do with the slow progress of the pneumatic system; but, independently of that, there were other considerations that should be taken into account; there was a much greater outlay required in building a pneumatic malting than in an ordinary one. For according to Mr. Stopes' own view the ordinary maltings about the country were buildings of the simplest character, and the implements and labour employed were of the simplest and cheapest kind, and no engine or steam power was used. The addition of the latter, and consequently skilled labour, would of itself be a very serious item, the additional expense of which, unless in a large malt-house, would far outweigh any commercial benefit. Besides that, the fact of the manufacture of malt having been carried on in the same manner from time immemorial was in itself a reason to hesitate before making radical changes. It was only natural, therefore, that the maltster should require to see his way clear to a large increase in his output and improvement in the article produced, before deciding on so sweeping a change, and his reluctance should

not be put down entirely to prejudice. For malting on a large scale, and when power and water were cheap, and ground space valuable, a pneumatic system was the most advantageous as well as the most scientific method of treating the grain; in the instance mentioned by Mr. Hooper of Messrs. Perry's maltings in Ireland, the machinery was driven by water-power and there was an abundance of water for cooling purposes, consequently the system was worked under most favourable circumstances. Although now coming to us from abroad, the pneumatic system had been known in England a long time, and various patents had been taken out in respect of it. The first by Mr. P. Stead in 1842 was for various processes in the manufacture of malt both in the growing and drying. In the latter he seemed to anticipate the present double-floor kilns, or rather he started with the idea of four floors in the kilns, but worked with two. Unfortunately his patent was encumbered by various other alterations worse than useless, and the result was failure, and no one who saw Mr. Stead's original drawings would be surprised at the result, no doubt due, so far as the kiln was concerned, to the manner of manipulation, and not to the principle, which experience had shown to be correct and certainly an improvement. As to the priority of the introduction of the double floor, he believed that Mr. Flynn was contemporaneous with Mr. Stopes in adding a second floor to one of his kilns at Bishop Stortford.

Mr. TOMKINS said there was one slight inaccuracy in Mr. Stopes' paper with regard to the characters of imperial amber malt. There was kiln-dried amber malt, and imperial, or cylinder-dried amber malt, which were the same thing. He believed that the cylinder-dried amber malt required a temperature of nearly 400°, certainly a temperature over 350°. If Mr. Stopes had spoken of kiln-dried amber malt he would have been correct; but it did not follow that a temperature of 240° caused malt to become amber malt. At temperatures of from 220° to 240°, malt might be dried perfectly pale, with a quick draught of air through the kiln, and the products of combustion separated from the hot dry air; and the higher the temperature, the sounder the malt would be. He could not say that he had had any experience in the use of double floors in the manufacture of barley malt; but it appeared to him to be a disadvantage when the first piece was lowered that they must load the upper wire with green malt. A damper was thus put on the draught through the lower floor just at the time when a quick draught of air was required to pass through the grain. The grain on the upper floor ought to be dried down to

a percentage of moisture below 12° before it is dropped on to the lower kiln-floor. It appeared to him that a similar result to that claimed by a double kiln-floor might be arrived at with a single floor by wetting more frequently, that was to say, every two or three days, or as often as the process would allow, instead of every four days. By that means they might get through the same quantity of malt in the year. That would give a thinner piece on the kiln, thus obtaining the advantage which was claimed for the double floor, and at the same time avoid the disadvantage of damping the draught just at the time when a quick draught was most essential to the soundness of the malt lowered. He understood Mr. Stopes to say that malt ought not to be used after it had been off the kiln three months. He imagined that that statement would point to the use of the pneumatic malting. Malt, however, certainly was used very much older off the kiln than that, and most brewers preferred malt more than three months old, if properly stored, as being more mellow and giving better fermentations than malt brewed so fresh off the kiln.

Mr. LENEY said a few months ago he had the pleasure of seeing the malting of Mr. Saladin in full work. He had himself had the double kiln-floor at work all the season, and he could speak very highly of it.

Mr. PRIOR said that he was very much interested in one point which he did not expect to hear referred to in the paper, and that was the amount of malt which was transferred to the kiln by machinery instead of by the shovel. He had had a machine put up for that purpose. It was fitted with ordinary cups for dry corn and was quite a failure. He then sent it back to the maker. He had now a machine being made after his own design and he found he had done the very thing which Mr. Stopes had told them to do in his paper. The work was done by means of a web and roller. He could confirm the remarks which had been made by Mr. Nursey about Hermann's wire floor. Mr. Stopes had put up a new floor for him (the speaker) of that description, and he was much pleased with it. He was rather surprised to hear Mr. Stopes state that grain could be carried up at an angle of forty degrees.

Mr. HITCH said Mr. Stopes seemed to object very rightly to the great difference in temperature between the top of a piece of malt and the bottom, and yet he said that on the top floor in the double kilns, where the difference was greatest, the malt should lie for forty hours without being turned. He (the speaker) did not quite understand that statement. He had visited one or two maltings which Mr. Stopes had put up,

and although that gentleman's dictum was that it was quite unnecessary to turn the malt for forty hours, he (the speaker) had never found it so in the practice of any maltsters that had adopted Mr. Stopes' double-kiln plan. One had told him that it was never more than three or four hours without being turned or ploughed, and another said it wanted turning every three hours in the day, otherwise the roots ran at the top in all directions.

Mr. STOPES, in reply, said that although Mr. Nursey had referred to the difference in section between the round and the flat wires, he had not mentioned the very great difference which the present construction of floor gave to the actual air space. He (Mr. Stopes) had for some time contended that it was most important to have as much air as possible, within due limits, passing through the malt. That section enabled them to have a much greater air space per superficial foot than any other with which he was acquainted. The échangeur of which Mr. Nursey had spoken so favourably, presented the means of accomplishing several most desirable ends. One was to enable them to cool and purify and exert a variety of influences upon the air, at a comparatively small outlay and in the most favourable manner. With regard to Mr. Kinsey's questions as to the difficulties of Australians and Canadians in working pneumatic maltings, he had had very little experience in that matter either in the Colonies or in Canada; but he had put up a number of ordinary maltings and built a number of double kilns in Australia and New Zealand, all of which were working well, and he believed that they made fairly good malt. Those who did know how to make the pneumatic maltings work, did not not understand the right conditions, for it ought to be a much more certain process to make good malt in a pneumatic house than in an ordinary house where such great differences of temperature existed as in the Colonies and in Canada. Mr. Kinsey also asked why the plan of utilising the actual products of combustion was not adopted in kilns. In Mr. Tomkins' kiln there was a series of furnaces which did not allow the actual air which went through the fuel to go through the malt which was lying on the floor. The air going through the malt was heated by coming in contact with a series of flues, and although that gave a very high temperature there was not the power to control the temperature. It had been the opinion of practical maltsters for many years that it was most desirable that malt should come into contact with the actual products of combustion, so that it might get the creosoting influence or the empyreumatic influences of combustion. Although they might possibly make malt perfectly dry by putting it into an oven, they would not

get a properly flavoured malt by such a process. Mr. Kinsey had also asked why kilns in old houses could not be more readily altered. He (Mr. Stopes) had altered a considerable number of kilns in old houses, and invariably with favourable results. Mr. Hitch seemed to think that mouldy grain was the necessary consequence of pneumatic working; but if he had seen samples of malt which he (Mr. Stopes) had, at the exhibition at the Agricultural Hall last year, he would not have been able to say anything about mould. If Mr. Hitch had seen any great amount of mould in malt made by the pneumatic process, the house could not have been rightly constructed, or the process could not have been rightly worked. With regard to the conical steeps, he had not laid any very great stress upon them in his paper, but any one who had seen them working must know the great advantage of being able to steep barley by that means.

With regard to the advantages of two-floor kilns he would point out to Mr. Hooper, Mr. Tomkins, Mr. Inskipp, and several other speakers, that the subject of drying malt on two floors appeared to be seriously misunderstood. Let them suppose the case of a kiln which had been worked for some years, and which was capable of drying the malt grown in a house steeping 60 quarters of barley, which, owing to the inaccuracy of the measurements by the architect, was really capable of growing 80 quarters. In order to steep 60 quarters, they had to allow some 12 or 16 inches of grain upon the drying-floor. It took nearly four days to dry it properly, and it had to be turned over very frequently indeed, in order to prevent the backs running out, and other evils. If they put another cistern into that house, and made it steep 40 quarters every other day, instead of 60 every 4 days, and put in another floor to the kiln, they entirely altered the character of the house. At the outset they would have 8 inches of grain lying on the floor, and in the course of a couple of days that would have lost 80 or 90 per cent. of its moisture and about half of its bulk. At the end of two days they would dispose of that grain by dropping it through the floor, and then they would consequently load the under floor with 5 inches of "hand-dry" grain. They would then load the upper floor with a second steeping, and the result would be that they would have 5 inches of corn on the lower floor, and 8 inches of corn on the upper floor. That would give 13 inches of corn for 80 quarters, instead of 12 inches for 60 quarters, which there would be if there was only one kiln-floor; and it would be found that the air would get more freely through the two floors of 5 inches and 8 inches, than through one floor

of 12 inches. In the case of the two floors being used, there would not be the same necessity for turning. All that would be needed would be to lighten the grain up with a plough-fork or a pronged shovel, in order to get a free circulation and upward escape of air through it. The practical result was that, instead of throwing away the heat owing to the free radiation from the upper surface, they would be utilising the fuel a second time, and effect a most important saving of coal. That, however, was but the smallest economy, because they had the power to control the conditions of the temperature very much better than in any single-floor kiln which he had ever seen. Mr. Inskipp had spoken of the cost of pneumatic houses. Houses of small dimensions, say for only 20 or 30 quarters, were necessarily more expensive in proportion to their size than the larger ones, but when they built a house for a steep of 100 quarters, the cost of a pneumatic house was materially reduced. He could build a 500-quarter pneumatic house at half or one-third of the cost which would be needed to make English houses of 500-quarter steep. He had seen several houses which steeped nearly 200 quarters on the English plan, and he strongly condemned them. He maintained that it was impossible for any maltster rightly to regulate the temperatures in the centre of a floor which was 80 or 100 feet wide. He strongly condemned any growing-floor which was more than 50 feet in width. With regard to the temperatures, Mr. Tomkins was quite right, and he (Mr. Stopes) was quite right too. Of course it was impossible in a comparatively brief paper to give every minute detail. Mr. Tomkins spoke of the disadvantages of a second floor, and he seemed to think that steeping very frequently, say every two or three days, would answer the same purpose. He trusted that Mr. Tomkins did not think so still. In an old house, in which there was free radiation from the upper surface of the malt, the temperature of the top surface might be 50°, or 60°, or even 90° lower than that of the bottom surface. He contended that if one portion of the malt had never been raised to within 90° of another portion of the malt, the two portions could not be alike. It could not be expected that malt which had been dried at a temperature of 240° could be of the same kind as malt which had been dried at 150°. Brewers had put up with it, no doubt, in the past; but he contended that in future years they would not buy malt concerning which the maltster could not say that every kernel had been within 50° of a given temperature. He had never yet seen a man so skilful with the shovel, that he could ensure that the malt which was lying at the top could be brought to the

bottom, in order to get the proper temperature. He did not think that the laying of malt in a heap without access of air was sufficient to modify its constituents to the required extent.

With regard to three months' malt, he believed that many brewers were of opinion that malt which had been properly stored for three months was in about its best condition. Mr. Prior had referred doubtingly to the belts for carrying grain at an angle of forty degrees. He (Mr. Stopes) had seen a number of them, and he could only repeat that they did carry up the malt at that angle. He believed a chain with cups was very harmful to the green malt, because malt which was fit for the kiln was in its most tender state, and should it receive any injury and be put on a kiln where it would be kept forty or fifty hours at a temperature of 110°, it had power to create a large quantity of mould. Mr. Hitch said he had never met with any one who had worked without turning the malt. He (Mr. Stopes) could introduce him to a number, and he would be able to see malt being made in a very good manner without being touched upon the kiln otherwise than by being just ploughed. He believed that, after a few years, maltsters would abandon the practice of turning the malt. He had great hope that the maltsters would gradually learn those things which were beneficial to the users of malt as well as to the makers.

The PRESIDENT said Mr. Stopes had brought before them a very interesting subject, and one which seemed to show how great had been recent advances in the use of machinery for malting, to perform work which formerly had been done entirely by hand. It was remarkable how, in this instance, legislation had quite revolutionised an entire trade. We did not often now see any manufacturing process which had gone on for years so suddenly altered, and brought under control of the chemist, the botanist, and the engineer, as that of malting. They all knew that dry fungoid growths were entirely prevented by the free access of air; and it seemed to him that the same thing held good in malting as in other things. The angle of forty degrees at which the grain was carried up by belts seemed to be a very considerable one. He believed that the first use of belts, for carrying grain on any extensive scale in England, was made by Sir William Armstrong at the Liverpool Docks. The Members were much indebted to Mr. Stopes for bringing forward the interesting subject of malting; and he thought that one result of it should be a further improvement, and an advance in malting, for engineering seemed to be taking its place in malting as it had done in many other scientific processes.

June 9th, 1884.

ARTHUR RIGG, PRESIDENT, IN THE CHAIR.

SOFT *versus* HARD WATER FOR MANUFACTURING PURPOSES.

BY J. C. FELL.

THE object of the author in submitting this paper to the Members of the Society of Engineers, is to draw attention to a subject which, apparently trivial in itself, is found to be of immense financial importance in a large number of manufacturing industries, and he hopes to sufficiently explain the scientific bases upon which the Members of this Society may themselves have to deal with the subject in processes or manufactures coming under their direction and superintendence. To deal with the subject systematically, it is first necessary to define clearly the distinction between hard and soft water. Soft water is chemically pure, or merely mixed with organic matter. Distilled water perfectly fulfils the former of these conditions, and is essentially soft. This is owing to an important consequence of evaporation, which should be remembered by all engineers, in this, and similar subjects, viz. that the water upon evaporation leaves behind all the mineral matters that may be in solution with it, as precipitates in the evaporating-pan. This is instanced in a well-known case, in the manufacture of salt by the evaporation of brine; the salt being precipitated, while the water passes off in a chemically pure vapour. All rain-clouds, then, which are formed by the evaporation of water from the sea and other large liquid surfaces by the heat of the sun, are chemically pure, and rain therefore falls to the ground as soft water. In passing, however, through the atmosphere the rain-drops absorb a considerable proportion of free oxygen, and also sulphuric and carbonic acids, which are always present in the atmosphere. These acids and oxygen do not of themselves in any way alter the character of the water, or render it hard, but have the important effect of enabling it to take up earthy salts into solution whilst percolating through the earth, which eventually

cause the water to become hard. The absorption of carbonic acid by soft water does not take place only, or even chiefly, while falling through the atmosphere, but is greatly effected afterwards, whilst the surface water is percolating through the open interstices of the earth, in which large volumes of carbonic acid are held imprisoned as it were. The result of this charging of the water with free carbonic acid in solution, is that the water is capable of forming, and holding in invisible solution, large quantities of carbonate of lime, chiefly formed by the passage of water through deposits of chalk. Similarly, the sulphuric acid combines with chalk to form a solution of sulphate of lime, and the other acids unite with other minerals to form salts. The carbonate of lime forms what is called "temporary hardness," and is so termed because any treatment of water by which it is heated to boiling-point causes the occlusion, or giving off of the free carbonic acid gas, and hence the precipitation of the larger proportion of dissolved carbonate of lime, and this even without total evaporation, as the carbonate is no longer held in solution by alkaline or neutral water. Many waters, however, are permanently hard, and cannot be rendered soft by simply being raised to boiling-point. These waters owe their hardness chiefly to sulphate of lime being in solution therewith, as also chlorides of calcium and magnesium, and nitrates and nitrites of the same bases. Although these mineral matters cannot be thrown down by the raising of the water to boiling-point, as is the case with the carbonate of lime, it must not be forgotten that all these mineral sediments are freely deposited as crystals by the total evaporation of the water, in the same way as salt from a solution of brine.

These considerable solutions of mineral salts in water used for ordinary evaporating and general purposes, offer an immense amount of trouble and financial loss, though the cause in itself seems so trivial a one to those who may not have given the matter their immediate attention. That these difficulties are very generally to be met with, particularly in our own London district and suburbs, may be realised when it is stated that all Thames and New River water has about 14° of hardness, which is equivalent to holding about 3½ oz. of carbonate of lime per 100 gallons of water in solution. Kent water is worse still, having something like 24° of hardness on an average, equivalent to about 6 oz. of carbonate of lime held in solution per 100 gallons. These facts are most easily tested and proved by the soap test. This consists in the treatment of the water by a clear solution of Castile soap in alcohol in the standard proportions of 10 grains of soap in 1 litre of alcohol. The soap solution is added from a graduated tube in successive quantities, representing

1 grain of soap. If curding ensues, the soap is being converted into an insoluble stearate or oleate of lime by the carbonate of lime in the water. When curding ceases and saponification ensues, the carbonate of lime is neutralised and the measure of the hardness of the water is ascertained.

With regard to manufacturing processes affected by this temporary and permanent hardness of water, it is evident that one of the most important applications for the attention of a body of engineers, such as the present, is the evaporation of water in ordinary steam-boilers. The facts are practically well known, no doubt, to most of you by their results, but the following estimates of the gross costs and loss due to sedimentary deposits may be of interest. Taking the ordinary rate of evaporation of a 30-horsepower boiler, viz. 1 cubic foot of water per nominal horsepower per hour, and the percentage of solid matter in the water evaporated at $3\frac{1}{2}$ oz. per 100 gallons, solid deposit is thrown down at the rate of 4 lb. per day. This reaches approximately 1 cwt. per calendar month, which gives a graphic idea of the amount of covering of the heating surface actively going on in boilers fed with hard water. The author has received authentic information that in a large factory on the south of the Thames, sediment has been found to collect to the extent of half an inch in thickness in the space of three months, when undisturbed and uninterfered with by any chemical substances. On the same authority it has been stated that a $\frac{1}{4}$-inch deposit causes a loss of 25 per cent. at least in evaporative efficiency of the fuel, without taking into account the great danger of overheating and the consequently rapid deterioration of the tubes or plates. If, then, this result of 25 per cent. loss of fuel be taken as the maximum that is likely to be allowed before remedial measures are put in hand, it is evident that 12 per cent. loss of fuel is a fair average with constant cleaning every three months. In a 30-horsepower boiler this would represent at least 1 ton of fuel a week wasted, irrespective of the inconvenience and cost of the constant cleansing required.

From the remarks in the earlier portion of the paper, it will be easy to realise what takes place in the course of such evaporation. So soon as the carbonic acid gas held in solution is given off at an early stage of boiling, the carbonate of lime forming the temporary hardness of the water will precipitate as crystals, tending to adhere firmly to the heating surface of the boiler. After total evaporation has taken place or when saturation point is reached, these deposits will be increased by the sulphate of lime or other chlorides and nitrates held in solution by the water. The grease or other

viduals, are frequently lost sight of in the case of large institutions, workhouses, hospitals, &c., where the evil becomes of commercial magnitude.

There are, however, other obscure and probably comparatively unknown evils arising from the general use of hard water, viz. its injurious effects in the long run upon both vegetable and animal life. The author has information from a large horticulturist that having carried out experiments with the use of hard water for the watering of plants, he found that the continued application of such water, where the plants were otherwise covered from the rain, destroyed certain plants in the period of about eighteen months, and impeded the growth of others. Further information has been received from large stock-breeders that owing to the noted bad effect of the supply of nothing but hard water for drinking purposes to cattle and horses, it pays the breeder to send long distances for a supply of soft water for his stock. Hard water is also known in the experience of the managers of aquariums to be prejudicial to the health and life of certain fish.

To deal with the serious disadvantages already referred to many remedial processes have been put into operation. These may be classified as follows:—

1. Chemical processes by which the salts producing temporary and permanent hardness are endeavoured to be precipitated and thrown down before use.

2. A preliminary treatment of the water by simmering, which, by the occlusion or driving off of the free carbonic acid, will serve to disengage and precipitate the carbonate of lime forming temporary hardness.

3. The application in closed vessels, such as boilers, &c., of chemical reagents, to effect the precipitation in a manner other than that of the crystals adhering to the heated surface, so injurious to the transmission of the heat, or in such a manner as to tend to prevent the deposition of the crystals altogether.

4. The application of electrical currents to prevent the deposition of the crystals upon the heated surface.

Of these, under the first heading, the process invented many years since by the late Prof. Clark, of Aberdeen, is one of the best known. The principle of the process consists in adding a solution of caustic lime to the water to be softened. The effect of this is to abstract a portion of the carbonic acid from the carbonate of lime in solution, both portions of lime being thus brought into the condition of a neutral carbonate, which becomes gradually precipitated. The water to be softened is treated by a solution of caustic lime, proportioned according to the [illegible]s, from 1 to 2 of lime water, to 9 of

hard water. The quantity of lime which is required for the water for which the process is employed, may thus be added as frequently as necessary to the great bulk of the water to be softened, as contained in one or more reservoirs lined with concrete. Care must be taken to render the water as nearly as possible neutral, for any excess of free lime would be very objectionable. This process of course only deals with the carbonate of lime, and does not throw down the sulphate or other salts, which give to water what is called its permanent hardness. As, however, the permanent hardness is generally small in degree as compared with temporary hardness, this process, though far from accurate in its nature, or easy in its use, has been largely adopted by itself, and when combined with improvements invented by Mr. John Anderson Porter. The essence of Mr. Porter's improvements is that the precipitate is caused to fall upon screens, and thus forms a filtering medium, obviating the necessity of numerous tanks, requiring time to settle, which constitutes the great drawback to Prof. Clark's original method.

What the author considers a decided improvement upon the process has been lately invented and applied by Mr. P. A. Maignen, whose name has now been so long associated with filtering operations. The material specially invented by him for his process is added to any volume of water to be softened, and by the fineness of the powder, which gives great permeability and thus ensures a certain action of the reagent and permits proportioning with exactness, and by the peculiar successive character of its reactions, produces a successive deposition and precipitation of not only the carbonate of lime, but the sulphate of lime and other mineral salts, thus removing both the temporary and permanent hardness. As softening by this process can readily be effected by a regular feed to comparatively small successive volumes of water, there are no large reservoirs necessary for the process, but the water may be effectively softened by an automatic feed, regulated to suit the supply.

Under the second heading of treatment for softening by simmering. This very simple means of partially dealing with the evil is within the reach of any engineer. There is usually waste heat up to at least a temperature of 212° available in flues or chimneys which could be utilised for the keeping warm, approximately to boiling-point, of the feed-water, before being fed into the boiler, and the occlusion of the carbonic acid gas so produced would serve to precipitate the carbonate of lime, and thus remove the temporary but larger portion of the hardness of the water before the water is admitted into the boiler or other closed vessel at all.

Under the third heading, the addition of chemicals to the water in the closed vessel, such as a boiler, cannot, in the author's opinion, be recommended, as it tends to permit an excess of the reagent being introduced, creating unknown and possibly injurious acid or alkaline action upon the material of the closed vessel or boiler.

Under the fourth heading, a curious though well-known electrical phenomenon has been noticed as associated with the deposition of the crystal salts on the heating surfaces of boilers. This is of the following nature:—That from the surface upon which the crystals are deposited, a current of electricity is developed, returning back through the water to complete the circuit. The phenomenon was noted by Mr. Field, whose name has been so long known in connection with the "Field" boiler, and he has successfully attained the almost complete prevention of the deposition of crystals of salts upon the heating surface of evaporating vessels, such as boilers, by the introduction of an external weak electrical current in the opposite direction to that generated by the natural deposition of the crystals. This serves to prevent scaling on the heating surface in proportion to the strength of the current employed, the solid or mineral matter being thrown down as a powder to the bottom of the boiler, from whence it is easily brushed out or blown out in the usual way.

From the foregoing résumé of the scientific and chemical causes for the deposition of scale from water upon heating surfaces, and the references to well-known and approved processes for dealing with the difficulty, the author hopes sufficient has been said to indicate the difficulties and dangers and to point out simple remedies.

[*The paper was illustrated throughout by experiments.*]

DISCUSSION.

Mr. BALDWIN LATHAM said there appeared to be a great deal of mystery about the process for softening water. He should like to know what was the material used for softening which had been so strongly recommended. As an engineer he should certainly never recommend any one to adopt a process for softening water unless he knew what was to be put into the water in order to soften it. They were told that Maignen's preparation was a powder. They could assume that. A great many compositions might be made into powders. He should conclude himself that it was a mixture of lime and carbonate of soda or caustic soda; at least that was what it

tasted like. If they knew what the material was, they could judge of its merits. It appeared to be a very expensive material, for he found that it was advertised at sixpence a pound, and that one pound would only purify from three to five hundred gallons of water. By the ordinary lime process they could purify a thousand gallons at the cost of a farthing. To pay a shilling for what they could do for a farthing was not a measure which any engineer would advocate at the present day. Referring to the experiments, there seemed to be something very wrong in the mixtures on the table seeing that they had not got, with a mixture of sewage and London water, a greater amount of turbidity than had appeared. He should like to know how hard the water was to which the lime-water was added, and what was the strength of the lime-water. They knew that in Prof. Clark's process if sufficient lime was added turbidity took place at once. The Porter-Clark and Atkins processes of softening water were very similar to this process in the fact that the water was filtered. The Atkins process was almost identical with that adopted here. Lime-water was mixed with the water in proper proportion, and then it had to be passed into a tank, and from that tank it was passed into filters. The filters were cleaned by mechanical power when necessary. One of the newest of all the processes for softening water, and which had been at work in this country, was one described in a pamphlet by Mr. Howatson. The pamphlet was certainly one of the most sensible which he had read upon the question of the purification of water. There was no secret whatever in any part of the scheme. What Mr. Howatson recommended was not a process, but an apparatus. The apparatus was extremely simple. If it was as efficient as was stated by the author, it bade fair to compete with all the other modes which were now before the public. Simply to call a thing by a grand name, and sell it at so much a pound was not the way to get an engineer who knew his business to take it up. The process of softening water was one of great antiquity. The softening of water was practised long anterior to the invention of soap. The first mention of the manufacture of soap was in the 'Natural History' of Pliny, who died A.D. 79. Before that period, lyes or compositions of various substances were used for cleansing purposes. The lyes were made principally by passing water through wood ashes, or lixiviating with wood ashes. In many of the southern countries natural soda was used for the same purpose. In the Bible, the lye of wood ashes was mentioned, and in another instance there was a reference to fullers' soap, or what is supposed to have been soda. The use of lime for softening water seemed to have been known early in the third century. Every alkaline salt, separately and mixed, had

been used or recommended as an agent for softening water, and there was no room for further invention in that direction. Probably it would be found that the only new feature in the process under discussion was the labour-saving appliances by which the softening process was to be brought about. He had not heard from the author of the paper any reference to the influence of the hardness of water upon health. No advantage had ever been shown to arise from the use of soft water from a sanitary point of view. He believed it was admitted that waters which contained an excess of soda in solution were extremely injurious in certain urinary disorders, but the idea that hard water had a tendency to produce stone had been exploded. The only reason given for it was, that it was said that more people died of stone in Norfolk, and especially in Norwich, than in any other parts of the country. But it so happened that at the period when this fact was noticed a celebrated doctor had taken up his quarters at Norwich, and people suffering from the disease went to him from all parts of the world; and it was in consequence of this that death from stone happened more frequently in Norfolk than elsewhere. Since the attraction for such patients had ceased, Norfolk suffered no more from complaints of that description than other parts of the country which had perfectly soft water supplies. The author had stated that soft water was better for fish than hard. It was, however, known that all round the neighbourhood of London the finest trout were found in the Wandle or the Darent and other hard water streams. It was not quite the thing to say that fish could not thrive in chalk streams, for those persons who preserved trout in such streams knew that they had the greatest difficulty in keeping down other fish in order to give the trout fair play. Hence hard water in its natural state was not prejudicial to fish; but probably hard water taken directly from a well, in which the aëration would be carbonic acid, would be destructive to fish or extremely injurious. Most river waters were very hard except in the region of the primitive rocks. Chalk streams were the very places where the fish bred, and the fish in them were always extremely healthy. The great detriment to a chalk stream seemed to be pollution of an organic character. It had been shown by Dr. Clark and by the River Pollution Commissioners of 1874, and also by Mr. Wanklyn, that the softening of water by the lime process really tended to remove much of the organic impurity from water, so that in all probability the softening of the water would be extremely beneficial provided they did not put into the water something which was deleterious. Dr. Clark's softening process was, no doubt, a grand discovery which had been a great public advantage, and he (Mr. Latham)

wondered that the author of the paper had not described that process more at length. It was well known that every pound of pure chalk as it was taken out of the ground contained 7 oz. of carbonic acid and 9 oz. of lime. Chalk itself was only soluble in water to the extent of about 1 grain per gallon; but if the 7 oz. of carbonic acid which would be driven off by burning 1 lb. of chalk were allowed to combine with 1 lb. of other chalk there would be immediately formed 23 oz. of bicarbonate of lime. That 23 oz. of bicarbonate of lime would be soluble in water, and this was the ordinary state in which it existed when water had passed through chalk, red sandstone, oolites, or lias, all of which more or less contained lime or carbonic acid and lime. Any water containing carbonic acid would take up chalk in the proportion stated. If 1 lb. of chalk was burnt and 7 oz. of carbonic acid were driven off, there would be 9 oz. of lime left. If 9 oz. of lime were added to the mixture containing 23 oz. of bicarbonate of lime, the 9 oz. and the 23 oz. added together would make 32 oz., and therefore there would immediately be formed 2 lb. of carbonate of lime. This substance being insoluble in water except to a slight extent, the 2 lb. of carbonate of lime would be precipitated. This process of Dr. Clark's was a very beautiful one, and it was certainly a wonderful advance in chemical science to bring about such a result. He (Mr. Latham) was afraid that the small progress which had been made with this process of softening water could never have repaid Dr. Clark for his labour, and the great advantage which he had bestowed upon the public. The paper stated that the precipitate which was produced by Mr. Maignen's powder contained in all probability carbonate of lime and sulphate of lime. He should like the author to tell them how sulphate of lime could be precipitated from water. Mr. Fell had told them clearly that the lime-water could only affect the carbonate of lime and could not affect the sulphate of lime. Therefore there must be something besides lime in the author's composition. If the author could tell them how it was possible to make sulphate of lime insoluble in water, he (Mr. Latham) would be glad to know. He had always thought that it was soluble to the extent of 1 part in 500 by weight of water. What really happened with regard to the sulphates was not that they were ever precipitated, but they were changed. The sulphate of lime was converted into sulphate of soda, which itself remained in solution to a very much larger extent than sulphate of lime, and was not so liable to be precipitated. In fact they had the same process goingon in London. If any one would go to the outside circle of London and draw a sample of water from the chalk wells, he would find a certain degree of hardness in the water. If he

would come to an intermediate well, say at Wimbledon, which was not very far from the area covered by the tertiary strata, he would find that the water was changed in its character. In passing from the outside chalk area under London it had changed, and there it would be found that salts of lime had been replaced by salts of soda, until they came into the very heart of London. The water found in the deep wells in the centre of London had only some 4° of hardness, although it had 16° in the outer circle. It had exchanged the calcareous salts for salts of soda, and so the water was soft although it contained a large amount of salts in solution.

Mr. HOWATSON, in explaining the Gaillet and Huet process, said that when a liquid holding in suspension a solid body was contained in a vessel in a state of rest, the solid body, if its density were superior to that of the liquid, tended to fall to the bottom, and did so fall after a longer or shorter period. The length of the process of deposition depended not only upon the nature of the liquid and the nature of the solid, but also upon the shape of the vessel. Given the nature of the liquid and that of the solid, the question was to find what form of vessel permitted the most rapid deposition. It was found that the deposition was more rapid in a shallow vessel than in a deep one. That was natural, seeing that in a deep vessel the solid molecules gradually sinking from the upper levels disturbed the lower levels. The lowest stage, which would rapidly become clear if it was isolated, received one after the other all the impurities of the upper sections. That observation would lead one to select as most suitable a vessel of shallow form, one in which the water would rest in a shallow sheet. It would be observed that in the top part of the glass containing water which was being softened by the Clark process, there was about one inch of perfectly clear water; the idea struck Messrs. Gaillet and Huet that if the glass was divided into layers of 1 inch each, the whole column of water would clarify as quickly as the top layer, so that a column of water taking fifteen or sixteen hours to clarify by the Clark process, would only take two to three hours by the Gaillet and Huet process. Their apparatus consisted of a rectangular reservoir, divided vertically by a series of diaphragms inclined at an angle of forty-five degrees which were riveted alternately to opposite faces. Those diaphragms were themselves formed of plates inclined at the same angle, so that the whole apparatus consisted of a series of alternating compartments, all of whose sides were inclined at an angle of forty-five degrees. Besides, by the arrangements adopted, all the plat[illegible]ned towards the same face of the apparatus, where they [illegible] series of discharge cocks. In consequence of

the inclination of forty-five degrees the deposit descended gradually to the bottom of the compartments, and was thus removed from the action of the current, in fact it collected together in a portion of the water situated without the active stream, and from places where once deposited it could not be carried away. The process of clearing out the deposit was very easy.

Mr. LATHAM said that he should like to know what advantage was to be got from softening the water for brewing. He had always been taught that if they boiled water they got exactly the same degree of softness as they would get by the use of a softening process. He presumed that in a brewery the water would be boiled a sufficient length of time to soften it. What advantage then was to be derived from carrying out an additional process for the same purpose. The carbonic acid was expelled by boiling, and precipitation took place. With respect to the Porter-Clark process in its present form, he regarded it as the most convenient process which they had, because they could pump the water from a well, pass it through an apparatus, and deliver it at a distant point, without its ever coming into contact with the atmosphere.

Mr. W. G. PIERCE said he had had five years' experience of softening water by means of Dr. Clark's process at the Canterbury Waterworks. It was well known that brewers always preferred hard water. They sank a well on their own premises where they were able to do so. At Aylesbury, after the water was softened by Dr. Clark's process, the brewers hardened it again by adding gypsum. He had found by calculation that the cost of softening by Clark's process was just a farthing for each pound of material used, including labour and everything. The cost of softening a thousand gallons of water was $\frac{4}{10}$ of a penny. At Canterbury they had to contend with the difficulty that some colours would not stand in the softened water, and laundry-women used to complain that dresses (inferior dyes) were spoiled in consequence. The quantity of chalk abstracted was about 25 oz. per 1000 gallons. Cost was incurred at Canterbury in bringing lime from Chatham (28 miles distant) for the softening process, for the chalk of the district was not suitable. The lime used was made from the soft upper chalk. Most persons preferred soft water for washing purposes. The water company at Canterbury would have had some difficulty in obtaining customers if they had not been able to supply soft water, for hard water could be easily obtained by sinking wells 15 or 20 feet deep in the upper chalk. The unsoftened water would clog up a 1-inch diameter pipe solid in about twelve months. One advantage of the processes recently patented, viz. the Porter-Clark, Atkins, and Maignen's, over

Clark's process was the small space which the apparatus occupied. As to the proportions used, 1 gallon of clear lime-water would soften 8 gallons of the Canterbury water. Nitrate of silver was used as a test for excess of lime, so that there might not be more used than was just sufficient to deposit the chalk, reducing the hardness from 16° to 4°.

Mr. JOHN PORTER said it occurred to him when the experiment of treating water by Clark's process was performed by the author of the paper, that sufficient lime-water was not added to the water. About one-eighth or one-ninth part of fully saturated and perfectly clear lime-water was often necessary; and rather less for the London water supply. He was rather surprised to find that after Clark's process had been known and in use for about forty years the proposal should now be made to use lime in a dry and powdered state for the purpose of precipitating the carbonates of the hard water, for lime dissolved very slowly and would be long in diffusing itself, whereas the solution of lime in Clark's process was very rapidly diffused and very quick in its reaction. Moreover, it was impossible to obtain two samples of lime of the same weight or measure equally soluble, owing to the irregularity or incompleteness of the lime-burning. His (Mr. Porter's) father had softened large quantities of water during some years, but had never proposed to do with dry lime what Dr. Clark had so long ago demonstrated was so quickly and surely attained by a solution of lime of exactly measurable strength.

Mr. HERBERT PORTER said soft water was of great use in brewing stout: but for ales hard water was necessary. Hence the success of the Burton ales. The difficulty of the majority of brewers was to harden the water. If it had 16° or 18° of temporary hardness, it would not take up much more hardening material in the form of sulphate of lime. But if the temporary hardness was first of all removed, and sulphate of lime added, the water would then take it up to a much larger extent.

Mr. FELL, replying to the discussion, said he should have been glad if the brewers present would have given a little information upon what, to engineers, was a comparatively unknown line of manufacture. The important point, upon which, probably, only brewers could give information, was whether the hardness of the water necessary for the light ales was not solely a necessity for the keeping of the ales. The principle which he had endeavoured to define was that a water to be absorbent of the juic[illegible]her the hop or the malt must be soft, but the produ[illegible]ot be a material which would keep, and therefore [illegible]s might be driven to the use of hard water. Th[illegible] using hard water at a disadvantage, but on

that point he required information. There was no doubt that the best stout which was brewed at Dublin was made from the soft water of the Liffey. Large quantities of the juice of the malt had to be extracted to make the stout. The question might arise, if hard water was necessary for the keeping of ale, how was it that stout would keep, this being made from soft water? He could only answer, that the highly carbonised malt might so affect the brewed products that they would have a greater tendency to keep than the lighter ales, which could only be induced to keep by the addition of gypsum, or sulphate of lime. That was a suggestion. In fact he must ask them to consider all those portions of the paper which related to various trades as merely suggestive. On the question of health he did not think it necessary to enlarge, as they were dealing essentially with hard and soft waters as applied to manufacturing processes. He simply referred to instances which had come under his notice, particularly with regard to the health of animals, plants, and fish. Mr. Latham, who had raised the question of the effect of hard water on fish, answered his own remark to his (Mr. Fell's) satisfaction. He admitted that very probably under certain circumstances the softening of the water was exceedingly beneficial to the fish. He (Mr. Fell) could not say that he could define exactly in what particular degree or under what circumstances it was so. He was only speaking of the fact that aquarium authorities had found it desirable to soften the water. He had referred to a large number of processes for softening water, and any expression with regard to them must be taken as coming from himself alone. The reason he considered that Maignen's process was a valuable and successful one was the fact that it dealt, by means of chemical precipitation, not only with the carbonate of lime, but with the sulphate of lime and the sulphate of magnesia. Everybody acknowledged that the ordinary lime processes, with which they were all acquainted, such as the Porter-Clark process, did not attempt to touch the sulphate of lime and the sulphate of magnesia. No doubt those who wished more information on the subject of Maignen's process could get it. He had not time to go into all the chemical proofs and reactions, but no doubt it would be very easy for the inventor to show anybody by satisfactory tests, that the carbonate of lime and sulphate of lime and sulphate of magnesia were deposited by his softening powder.

Mr. LATHAM asked Mr. Fell to tell the meeting what the powder consisted of. They could then form their own conclusions.

Mr. FELL said that he was not at liberty to state what the composition was. But he did not think that any one cared very

much what the mixture was if it produced the right results. No doubt the inventor had proved that the carbonate of lime, the sulphate of lime, and the sulplate of magnesia were precipitated, for the water became soft to a degree which could not be obtained merely by the lime process. That had been shown by the soap test that evening. That was the especial point at which they, as engineers and manufacturers, should look. A second very important point was to see whether, in the lime process, there was an excess of lime present. There was no doubt that a very great excess of lime must be present in order to throw down anything like a large proportion of the temporary hardness, without dealing with the permanent hardness at all. The essential points in Maignen's process were that the water resulting should be perfectly pure, and without an alkaline reaction, and that it should be tasteless. Those conditions could not be obtained by the ordinary lime process known as the Porter-Clark process, or the Clark process. It had been remarked by one speaker that the paper had not dealt at any great length with the Clark process. He considered the Clark process as the practical exemplification of the first principles defined in his paper, viz. the taking up of the free carbonic acid (which had been spoken of as bicarbonate by one of the speakers) by the addition of lime, causing a neutral solution of carbonate of lime which must then come down in precipitation. There was no doubt that it was a very valuable and important process.

The PRESIDENT said the subject was one which was interesting not only to a numerous body of manufacturers, but also to every individual person, whether an engineer, a brewer, or simply one of the general public. He regarded Clark's process as one of the most simple and beautiful applications of scientific chemistry which had ever been adapted to manufacturing purposes. Considering the numerous processes which had arisen from Mr. Clark's discovery and of which they had heard that evening, there appeared to be several almost distinct methods of arriving at the result required, namely, a softening of hard waters. No doubt the soap test could be relied upon as an absolute proof of the efficacy of the processes. The Maignen process seemed to some extent a mystery, but, as Mr. Fell had said, his results could be easily tested. Most secrets came out sooner or later, and perhaps they would one day know what were the ingredients of the powder which was employed in this process. They must all feel indebted to Mr. Fell for the valuable paper which he had brought before them, and for the interesting experiments by which he had ed it.

THE VACATION VISITS.

DURING the Vacation of 1884 the Members and Associates, following a practice which has been observed for many years past, visited several engineering and other works of professional interest. Three visits in all were made, the first, which took place on June 25th, was to the Locomotive Works of the Midland Railway Company at Derby. The party reached Derby by special train about midday, and were received by Mr. S. W. Johnson, the company's locomotive superintendent, and Mr. Thomas Clayton, the superintendent of the carriage department, by whom the visitors were conducted over the works. The visitors were first shown through the laboratory, where they examined samples of the materials used in the works. Thence they went through several shops of interest, passing on the road a powerful weighing-machine, by which locomotives weighing 46 tons, without their tenders, are so weighed that the load on each pair of wheels is measured and may be properly adjusted. A large number of locomotives of the different kinds were inspected and their peculiarities explained on the way to the immense erecting shops, turning and machine shops, boiler shops, smith shops, and foundries. There are on the Midland Railway 1700 locomotives, and under the control of Mr. Johnson are about 10,000 of the 46,000 servants of all grades of the company. From this number of locomotives, which is a mere index to the rolling-stock work, it will be realised that at the Derby Central Works an enormous area is covered by the shops necessary to keep the Midland system fully supplied with engines, carriages, waggons, and so on. There are here some of the finest and best equipped shops in the kingdom, the principal ones being 450 feet in length, and provided with every necessary for the economical production and repairs of stock. In the foundry the visitors saw, amongst other things, the moulding and casting of the chairs by which rails are held in place on the sleepers, and some idea of the extent of the line may be gathered from the fact that from 200 to 250 tons of these chairs are here made per week. In the erecting shops they saw engines in various stages of completion, and

amongst others the large new powerful engines for working the heavy fast traffic which modern conditions demand. These engines have cylinders 19 inches in diameter with a stroke of 26 inches, the driving-wheels being 7 feet in diameter. The two cylinders are brought very close together and cast in one piece, the great advantages secured by this arrangement being due to the employment of the Joy valve-gear, by which the use of excentrics is avoided. In continuing their passage through the works they passed through a turnery, where in one shop alone 450 hands are employed. From the locomotive department the visitors were conducted to and over the carriage and waggon department by the superintendent, Mr. T. E. Clayton. Here an area of several acres is covered by a splendid series of new workshops fitted with the best modern plant and with timber stores, and outside the shops is one of the largest stocks of timber to be seen in the country. Very large quantities of American oak are used, and in the drying stores were seen what would seem to be enough frame-pieces, buffer-beams, sole-pieces, planks, and so on, for waggons and carriages to stock the whole of the railways of the kingdom, but a little further progress through the carriage and waggon shops, where are hundreds of these in course of construction, soon dispelled this idea. The visitors were shown some of one lot of a hundred new carriages of most recent form and type, elegantly finished and designed with every attention to strength and comfort, and fitted with the Pintsch system of oil-gas lighting apparatus. The Midland Company has a number of trains thus fitted running on its metropolitan service, and not only is an excellent light given, but the cost per light is much less than with lamps, the cost for attention being exceedingly small. Some idea of the necessary area of the waggon repairing shops may be gathered from the fact that, added to the waggon stock already in its possession, the Midland Company recently purchased about 60,000 of the waggons belonging to private owners, but running on its lines.

The second visit was made, on August 21st, to the New Works of the South Metropolitan Gas Company at East Greenwich; the Chemical Works of Messrs. Sadler, Forbes, Abbott and Co. and the Blackwall Point Dry Dock. It may be premised that what is known as the South Metropolitan Gas Company is a triplicate of its former self, having been amalgamated with the Surrey Consumers and the Phœnix Companies. But with their united powers the combined companies have found themselves unable to cope with the steadily increasing demand for gas on the part of the public, although working up to the

maximum with their existing plant. That maximum means 450,000 tons of coal carbonised in the year. The average summer make is 20 million cubic feet of gas per day, which is the result of the daily carbonisation of 2000 tons of coal, the average winter make being, of course, much higher. Finding a steady increase of 4 per cent. in the annual demand upon them for gas, the South Metropolitan Company cast about for room to extend its borders, and in the end secured an Act of Parliament and acquired 130 acres of land, formerly market gardens, at East Greenwich, opposite to Blackwall, and on this land they are erecting the first instalment of their extensive new works. There the visitors were received and conducted over the works by Mr. George Livesey, one of the directors of the South Metropolitan Company, and his brother, Mr. F. Livesey, the engineer to the works, the designs for which have been prepared by both gentlemen. The retort-house at present being built is 942 feet long by 100 feet wide, including the coal-store. It will contain forty-five settings of retorts, ten retorts in each setting, and having 900 mouthpieces, and will be equal to the production of 5 million cubic feet of gas per day. This, however, is only a first instalment, and but one-twelfth of what will eventually rise on the ground, for there will be eleven more of these retort-houses, the whole forming one large building, 1200 feet long by 492 feet wide, and capable of producing 60 million cubic feet of gas per day. The coal will be landed on a jetty, which is in course of construction, and which is of T shape, projecting 390 feet into the river. The jetty will have a frontage of 450 feet when completed, and will be capable of berthing five vessels. The jetty will be laid with rails of about 4 feet gauge, and the coal will be run up to the retort-houses by locomotives. The river wall consists of piles well tied in, and having concrete slabs placed behind them, with a backing of earth. This wall will be 1400 feet in length, about 250 feet had been constructed at the time of the visit. Two gasholders, each 250 feet diameter and 60 feet deep, are being constructed; each will be double lift and will have a capacity of 5½ million cubic feet. Some trouble has been experienced in getting a good foundation for the gasholder tanks, the London clay proving very thin at this point. A quantity of peat, too, has been met with. Less difficulty was experienced with the foundations of the retort-house, the walls of which up to a certain point are of concrete carried on a series of piers and arches. Of course there will be the usual complement of washers, scrubbers, purifiers, and other adjuncts of gasworks. The gas will be conveyed through 4 miles of 48-inch pipes,

which will be laid from these works to the South Metropolitan Works in the Old Kent Road.

Although the South Metropolitan Gas Company have acquired 130 acres of land, the whole of it will not be appropriated to the gasworks. In fact, some portion of it is already occupied by the Chemical Works of Messrs. Sadler, Forbes, Abbott, and Co., at which establishment the Members of the Society were received by Messrs. Forbes and Abbott, and by them and by Mr. Field were conducted over the works. Here the tar produced by the South Metropolitan Company at their various works is brought alongside by barges and is pumped up into steam-heated tanks, which separate the water from it. From thence it is pumped into heating tanks on its way to the stills, the tanks being heated by the outflowing pitch from the retorts, which passes through the pipes. Thus a double effect is produced and two desirable points gained, the incoming tar being heated and the outgoing pitch cooled. The stills are Lennard's patent, and are capable of holding 8000 gallons each; they are 33 feet long by 6 feet diameter, and are made of wrought iron. In the ordinary stills the tar becomes baked on the bottom of the still over the fire, but in the Lennard's still a revolving agitator is used, and this keeps the charge in motion and prevents the formation of coke, thus effecting a saving both in fuel and in wear and tear. The first product of the still is naphtha, which is given over at a temperature of 100° Fahr. The products of distillation, as they come over, are run into underground tanks, with which the works are pretty well paved, and which consist mostly of old steam-boilers. From these underground tanks the products are blown off by air-pressure to any required part of the works. The naphtha is washed in lead-lined vessels with sulphuric acid, and is afterwards pumped into a still, the vapours passing off from thence forming benzole. The second product given off from the tar in the still is creosote, which comes over at 200° Fahr. This product is used for preserving timber and for other purposes. A portion, however, is converted into carbolic acid by being washed with a solution of caustic alkali. The carbolate is then run into a tank and neutralised with sulphuric acid, the resultant being carbolic acid, which is produced at the top of the contents of the tank. The third product of the still is anthracine, which comes over at 300° Fahr. and is cooled in open tanks, being afterwards strained through filter-presses. The oil passes out of the presses, leaving a solid residue, which is afterwards passed through hydraulic presses and subsequently used for the manufacture of alizarine, for which purpose it is

packed in barrels and sent to Messrs. Sadler's works at Middlesbrough. The final result of the distillation is pitch, which is conveyed away to the pitch beds and is used for making asphalte and for other purposes, large quantities being sent to France. What was formerly a drug in the market is thus converted into a variety of useful substances, some destined for still further conversion into some of the most important items of commercial enterprise. The Blackwall Point Dry Dock is also situate on the gas company's land, and was inspected by the visitors. A large vessel, the *Richmond Hill*, a twin-screw steamer of 5000 tons, was in dock undergoing repairs and alteration, and was examined.

The third and last visit of the recess was made on September 10th to the Telegraph Cable Works of Messrs. Siemens Brothers at Charlton. The visitors were received by the heads of the various departments, and by them conducted in several parties over the works and over the cable-ship *Faraday*, which lay in the Thames, taking in the second portion of the second Mackay-Bennett Anglo-American Cable, which formed the chief work then on hand at Messrs. Siemens Brothers. The first portion of this cable, about 1700 miles, had already been laid by the *Faraday* from Ireland to the Newfoundland Bank, and she was about to start with the second portion, which has since been laid from Newfoundland Bank to Nova Scotia, about 700 miles more. Before going over the cable departments, the visitors inspected those devoted to the production of electric-lighting apparatus. These included the electric-light shop, the electric-light engineers' shop, the insulator department, and the carbon department, besides which the visitors were shown the plant for lighting the works by electricity. In the electric-light section of the works the visitors saw Siemens' dynamo-machines of various powers being made, notably one equal to driving 1500 Swan glow-lamps of 20-candle power each, being the largest of its kind ever made. A search-light of 25,000-candle power was shown, as well as a variety of other lamps and electrical arrangements. An interesting experiment was carried out, in which a piece of iron wire 18 feet long and 5 millimetres in diameter was burnt to fragments in 1 minute 30 seconds by a Siemens dynamo of 100 volts and 250 ampères. In the electric carbon shop, where the carbons for electric arc-lamps are made, the materials are first ground and prepared, and then expressed through a die in a hydraulic press, the diameters of the carbon rods varying according to requirement. The rods are then dried and baked ready for use.

The principal materials used in the manufacture of telegraph cables are wire, indiarubber, gutterpercha, and hemp. In some cases the wire conductors are covered with indiarubber, and in others with guttapercha, the cores thus being formed. The indiarubber is obtained in its raw state chiefly from Para, and the first process of manufacture is to rid it of its impurities. To this end it is cut into pieces and passed many times through rolls placed in pairs and running at differential speeds, so that a grinding as well as a squeezing action is obtained. A stream of water is continually running on the rubber, which carries away the impurities; and when the water runs clear it is an evidence that the cleansing process is so far complete. After this purification, the rubber is dried at a moderate temperature, and afterwards rolled into sheets of three classes. One consists of pure rubber sheets, while in the other two sulphur and other necessary ingredients are incorporated with the rubber. The sheets are then cut into strips or tapes ready for use in the covering machines. In the wire-covering department the visitors saw the conductors being encased in strips of these rubbers of one kind or the other, according to requirement, by being passed through machines in which the wire is, so to speak, sandwiched in between an upper and a lower strip, the edges being carefully trimmed off. In one machine wire was being coated with the pure rubber, while in another a conductor was being inclosed first in a white and then in a pink-coloured rubber-casing. The coverings are afterwards solidified and made homogeneous by heat. Another department of those works is devoted to the covering of the wire conductors with guttapercha, which, like the rubber, has to be first purified and prepared. The raw material in this case is obtained chiefly from Singapore, and is first cut up into slices by machinery. It is then soaked and softened in tanks of hot water, after which it is taken to a machine called a "ticker," or "devil," where it is shredded and discharged into hot water. It then undergoes complete mastication in special machines, whence it is transferred to hydraulic presses, where it is forced through strainers of fine wire gauze, which arrest all remaining mechanical impurities. It is again washed and masticated in boiling water. Various kinds of guttapercha are afterwards blended, and finally rolled into sheets and stored. The wires are covered with guttapercha by being drawn through machines having specially constructed dies, in which the guttapercha is contained under pressure and kept plastic by heat. As the covered wires leave the dies they pass through troughs of cold water, and are led on to a second, and, if necessary, to a third

machine, according to the number of coats required. The insulated wire or core is conducted to the sheathing department, where it is first covered with hemp and afterwards with iron wire by machinery. It is then passed through other machines, in which it is covered with two more layers of tarred hemp wound on in opposite directions. The cable is now completed, and as it is made it is stored in tanks, of which there are eight in the large tank-house, each tank being capable of holding 400 miles of cable. In a second tank-house there are eight more tanks of smaller capacity.

From the tanks the cable is paid out to the ship which is to lay it under the Atlantic Ocean, or other sea, and from the tanks, therefore, the visitors followed the Mackay-Bennett cable to its storage on board the cable ship *Faraday*. This vessel is a twin-screw ship of about 6000 tons burden, and she can carry about 4000 tons of cable exclusive of coal and stores. She is 365 feet in length and 52 feet beam, and has a pair of compound engines of 1800 horsepower indicated, combined. She has three cable tanks, the main and aft tanks being 45 feet diameter and 30 feet deep, and each capable of holding 800 miles of cable. The fore tank is of smaller dimensions. There are three ballast tanks under the cable tanks, each of which will hold 300 tons of water. At the stern of the vessel is the paying-out apparatus, and at the head the picking-up machinery. She is fitted with steel-wire sounding apparatus, capable of taking soundings up to 3000 fathoms, which is about the maximum depth of the Atlantic. She has a well-appointed testing-room, where the visitors saw the cable being tested as it was being received on board. Testing forms a very important feature in the manufacture of deep-sea cables, and it is carried on throughout every stage from first to last, so that it is practically impossible for a fault or flaw to occur without detection. The electrical testing-room on the works was, therefore, inspected with interest, as was also the pressure tank, which is a very ingenious contrivance for testing a cable core under the same conditions, as regards pressure, as those under which it exists at the bottom of the Atlantic in its deepest part. The apparatus consists of a small circular steel tank only about 30 inches internal diameter, and some 5 feet deep, but weighing about 24 tons, the cover alone weighing 3 tons. Into this tank a length of about 2 miles of core, wound on a reel or drum, is lowered, and the tank closed and locked by the screwed cover, the ends of the core being connected with the testing-room. Hydraulic pressure is then applied up to 4 tons per square inch—6 tons per inch can be applied if necessary—the core remaining under

this pressure for about ten minutes, during which the electrical testing is carried on. The pressure is then taken off, the tested core lifted out, and another length put in and the operation repeated. This is another safeguard which the firm have against flaws which could not be ordinarily detected. In fact, everything that human foresight can do to ensure a perfect conductor and cable is done at the Charlton Works.

Besides the departments already referred to, the visitors were shown over the wire-testing department, the telegraphic instrument department, and the show room, where all the various telegraphic instruments and apparatus were assembled, many of them being seen in operation. The machinery in what is known as the old cable shop at the Charlton Works is driven by a pair of compound horizontal surface-condensing engines of 180 horsepower indicated; that in the new cable shop being driven by a beam-engine of 80 indicated horsepower. The cable works give employment to about 2000 men, another 1000 being employed in other directions.

October 6th, 1884.

CHARLES GANDON, VICE-PRESIDENT, IN THE CHAIR.

MODERN BRONZE ALLOYS FOR ENGINEERING PURPOSES.

By PERRY F. NURSEY, VICE-PRESIDENT.

IN order to mark the progressive steps of man, his early history has been divided into three periods, each being named after the materials chiefly used in them for supplying him with weapons, tools, and ornaments. Thus we have the age of stone, the age of bronze, and the age of iron. To these our own times have added the age of steel, which, of course, simply means a further, but most important, development of the age of iron. It occurs to the author that in like manner a similar development is going on in the present day with respect to bronze. But inasmuch as no generic term has been invented in these very inventive times for the new variations of that most ancient and useful alloy, he is unable to designate this fifth age by a new title, and so is content to consider it as a revival of the bronze age in a more advanced and more highly developed form. As, however, the age of stone was divided into two parts, namely, the old stone age, when men simply chipped stones, and the newer stone age, when they learned to grind and polish them, so perhaps it may be admissible to consider the present as the newer bronze age. Nor is it altogether inapt so to consider it when we see what a many varieties of bronze have been produced within the last few years, possessing very distinctive features from the ancient alloys, and some very remarkable qualities as compared with them, and how very numerous the purposes are to which these varieties are applied, superseding, as they do in many instances, iron, and even steel itself. These considerations, and the knowledge of the great value of these alloys to the engineer and the shipbuilder, have led the author to bring a few facts concerning them before the Society in the hope that they may prove interesting and possibly useful to the Members.

Although, for the purpose of drawing a fanciful parallel

between the past and the present, the author has taken his hearers back to the childhood of the world, when men first mixed and melted copper and tin together, and fashioned in a rude way from the resulting alloy their spear-heads, their hatchets, their earrings, and their bracelets, he does not intend to fill up the gap of the intervening centuries by following up the gradations by which this alloy was made at length to subserve the highest purposes of art, which, as regards statuary, probably reached a climax during the reign of Alexander the Great. He purposes only to touch upon a few points of metallurgical interest relating to the bronze of the past, and then by a rapid transition to come down to the present, and to enter upon a consideration of the various alloys of the bronze family which the ingenuity of our own day—stimulated, doubtless, by the necessities of the age we live in—has succeeded in rendering available for engineering purposes during the last few years.

Turning then, briefly, to the bronzes of the ancients, we find them varying considerably in the proportions of their two ingredients—for, in the main, copper and tin only were used—according to the purposes for which they were intended. Thus, modern chemical analysis shows that ancient bronze nails contained 20 of copper to 1 of tin; soft bronze consisted of 9 to 1, medium bronze 8 to 1, hard bronze 7 to 1, and mirrors about 2 to 1. The bronze weapons and tools of the ancients contained from 8 to 15 per cent. of tin. A Roman sword-blade found in the Thames showed 85·70 copper and 10·02 tin, whilst another one found in Ireland gave an analysis—copper 91·39 and tin 8·38. The bronze weapons of the Greeks and Romans have been found not only to be of the true composition for ensuring the greatest density in the alloy itself, but the cutting edges, by undergoing a process of hammering, were brought up to the highest degree of hardness and tenacity. And here the author would digress for one moment to observe that this is exactly the way in which he has seen the edges put on scythe-blades and other cutting tools in Styria, where he has seen some of the finest steel made in the simplest and rudest manner. Returning to the subject of the paper, it is to be observed that most of the ancient coins were of bronze, a small percentage of zinc being added in some cases to improve the colour. According to analyses made by Mr. J. A. Phillips, the quantity of tin relatively to copper varied very slightly, even over a range of 300 years. The following are the proportions of copper and tin, the other ingredients being omitted:—

Coins.	B.C.	Copper.	Tin.
Alexander the Great	335	86·72	13·14
Philippus V.	200	85·15	11·10
Athens	—	88·41	9·95
Ptolemy IX.	70	84·21	15·59
Pompey	53	74·11	8·56
The Atilia family	45	68·72	4·77
Augustus and Agrippa	30	78·58	12·91

Bronze pure and simple consists of a mixture of copper and tin in certain proportions. These proportions, as we have seen, are varied according to the purpose for which the compound is intended. Other metals, moreover, such as zinc, lead, phosphorus, manganese, silicium, and iron, may be and have been added without unclassifying the product, which is still called bronze, provided that copper and tin are the chief constituents. The bronzes of France are known to contain nearly always four metals—namely, copper, tin, lead, and zinc. It is also stated that some contain minute and variable quantities of nickel, arsenic, antimony, and sulphur. It is the addition to bronze pure and simple of certain proportions of one or other of the metallic substances previously referred to that constitutes the modern development of bronze manufacture, and which has given us some of the most useful and at the same time some of the most remarkable alloys known. These comprise no fewer than eleven distinct products, all of which find their uses in connection with the practice of engineering. These are—phosphor bronze; silicium bronze; manganese bronze; delta metal; phosphor copper; phosphor-manganese bronze; phosphor-lead bronze; phosphor tin; aluminium bronze; silveroid, and cobalt bronze. These alloys form the subject for present consideration, and they will be dealt with by the author in the foregoing order. There are other bronzes which are used as substitutes for gold in cheap imitation jewelry; but although they are in the main only variations of some of the bronzes with which the author has to deal, their applications are such that their notice does not fall within the scope of the present paper.

Attention was directed some years since to the use of phosphorus in improving the character of bronze for various purposes, and eventually with very successful results. The action of phosphorus on copper alloys is principally due to its reducing qualities, by virtue of which the oxygen absorbed by the molten metal is removed, or rather the oxides thereby produced are eliminated, and there is imparted to the metal

that degree of homogeneity, strength, and toughness which is peculiar to the chemically pure metal. The phosphorus in producing these effects is converted into cuprous oxide, which floats on the surface of the molten metal in the shape of a very fluid slag, whilst the superfluous quantity combines with the metal. This being the case, it is not desirable to add to the bronze a larger quantity of phosphorus than will suffice to reduce the oxide present. It is thought by some that the phosphorus itself imparts to the bronze the qualities of hardness and strength, and that therefore the more phosphorus put into the metal the better the result as regards hardness. This, however, is not the case, inasmuch as hardness would be obtained at the expense of toughness. The question of producing the various qualities of this class of metal depends not so much upon the quantity of phosphorus as upon the correct proportioning of the various ingredients, phosphorus included. Some of the alloys to which the author will direct attention are formed by the addition of a small proportion of a compound of phosphorus and copper or other metal to the bulk of the copper to be treated. Inasmuch, however, as great care is required in determining the exact proportions of the ingredients in making phosphor-bronze alloys, it appears to the author that it would be much safer and probably much more economical for manufacturing engineers to obtain the alloys ready prepared for the special purpose for which they require them, and which would, other things being equal, obviate all chance of failure by reason of a careless workman adding too little or too much of the phosphorised metal to the bulk.

Phosphor Bronze.

The first of the modern bronzes for notice in the order of time is phosphor bronze, which was invented by Dr. Künzel, of Blasewitz, Dresden, and was brought into practical use in this country early in 1873 by the Phosphor Bronze Company, who have from time to time patented several improvements both as regards alloys and methods of manufacture. Phosphor-bronze alloys are composed of copper, tin, phosphorus, and other ingredients in definite proportions, and are made to be either as ductile as copper, as tough as iron, or as hard as steel, accordingly as the proportions of the constituents are varied. The alloys used for rolling and drawing have very different proportions to those employed for castings, for bearings, and parts of machinery. The castings of the metal, owing to its great fluidity when melted, are perfectly sound and homogeneous. The strength, toughness, and durability are

desiderata, phosphor bronze is found to be far better adapted than gun-metal and brass, and in many cases than iron and steel. With regard to the applications of phosphor bronze, it may truly be said that their name is legion. This remark applies in the main to most of the modern bronze alloys presently to be described, so that, in order to save repetition, the author will here observe that chief amongst their many applications are the manufacture of wire, rods, tubes, sheets, ornamental castings, screw-propellers, pinions, cylinders, valves, bearings, bushes, and other parts of machinery exposed to friction. Phosphor bronze possesses the advantage of not becoming crystalline under the action of repeated shocks and bends, and is therefore well adapted for making wire rope, and as it is not acted on by corrosive liquids, as found in mines, or by the atmosphere, its value as a metal remains constant. It is being used in the shape of sheets for the hulls of torpedo-boats and steam-launches with satisfactory results. In order to ascertain its resistance to the chemical action of dilute sulphuric acid, two similar sheets of copper and of phosphor bronze were immersed in acid water, 10° Beaume strength, and at the temperature of the surrounding atmosphere; after three months it was found that the copper had lost 4·15 per cent. and the phosphor bronze only 2·3 per cent. Phosphor-bronze sheet, moreover, stands the action of sea-water much better than copper. In a comparative experiment made at Blackenberghe, lasting over a period of six months, between the best English copper and phosphor bronze, the following results were arrived at. The loss in weight due to the oxidising action of sea-water averaged for the copper 3·058 per cent., while that of phosphor bronze was but 1·158 per cent.

In making castings from phosphor-bronze alloys, a new or clean plumbago crucible is used, so as to avoid any admixture of other metals, and some charcoal or coke is kept on the metal during the melting to prevent oxidation. For large castings the moulds are thoroughly dried and dressed with a mixture of blacklead and water. Small work is cast green. In order to avoid segregation, it is necessary to pour phosphor-bronze alloys only just before the setting takes place. This is accomplished by cooling the molten metal by putting in ingots or runners, and when the metal no longer melts these, but adheres to them, it is a sign that the pouring should take place. Previously to pouring, the molten mass is well stirred by means of an iron rod covered with a paste of either fireclay or plumbago. Besides the original phosphor bronze with which the author has dealt so far, the Phosphor Bronze Company a year or two ago brought out two other varieties. These were

the outcome of an endeavour on the part of the company to meet as far as practicable the various requirements of engineers and millwrights, particularly in connection with parts of machinery exposed to combined friction and pressure. By slightly changing the proportions of the component parts of some of the ordinary mixtures, new alloys having very valuable and distinct characteristics have been produced, and which have been practically tried and proved. These new alloys are known as phosphor bronze duro A, and phosphor bronze duro B. Duro A is a very dense metal, adapted for all bearings carrying heavy wheels running at great velocities, and generally for all quick-speed purposes. Duro B is intended for the bearings of hot-necked rolls, and for all bearings having to withstand great pressure, such as plate- and sheet-roll bearings and for general engine purposes.

Having referred to the great durability of phosphor bronze under conditions of work, the author will here notice one instance out of several which have been brought under his notice from time to time. About two years since he inspected a pair of slide-valves, which had been then recently taken out of one of the North Eastern Railway Company's express engines after 6½ years' working, during which the engine had run 261,182 miles between Newcastle and Edinburgh. They were taken out to replace the cylinders with a pair of a different type.

The engine was of the following dimension:—Cylinders, 17 inches diameter by 24 inches stroke; four coupled wheels, 7 feet diameter; working pressure, 140 lb. per square inch; weight of engine in working trim, 39 tons 16 cwt.; weight of tender, 26 tons 4 cwt.

Mr. Fletcher, the assistant locomotive superintendent of the North Eastern Railway, states that the slides, in the 6½ years, had only worn down to the thickness at which they generally took out gun-metal slides, and that, had it not been that they were putting in a pair of cylinders of different type, he would certainly have let them run longer, as he considered them quite safe, taking into consideration the great superiority of phosphor bronze over gun-metal. The original thickness of these slides was 1 inch, and they were worn down to ⅝-inch thick. Gun-metal slides rarely exceed eight months' work when they are worn out. The cylinder faces were in excellent condition, the wearing being, as it should be, on the valves.

Tables I. and II. give the results of some comparative experiments made by Mr. David Kirkaldy with phosphor bronze and various other alloys and metals, whilst Table III. gives the results made with axle-bearings of various metals.

TABLE I.

RESULTS OF EXPERIMENTS TO ASCERTAIN THE ELASTIC AND ULTIMATE TENSILE STRENGTH OF TWELVE PIECES OF PHOSPHOR BRONZE, SIX PIECES OF ORDINARY BRONZE, AND ONE PIECE OF BRASS.

Description.	Stress.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Extension sets at	
	Elastic per Square Inch.	Ultimate per Square Inch.			Lb. 20,000 per Square Inch.	Ultimate.
	lb.	lb.	per cent.	per cent.	per cent.	per cent.
Phosphor-bronze	23,800	40,876	58·2	3·9	0·40	3·8
„ „	21,900	49,865	43·9	9·8	0·09	10·6
„ „	19,800	33,623	58·9	5·9	0·18	4·6
„ „	15,400	24,193	63·6	7·9	1·94	6·7
„ „	14,900	21,755	68·5	5·9	2·26	4·3
„ „	13,700	25,715	53·3	9·8	3·12	10·9
„ „	21,400	35,024	61·1	5·0	0·11	3·6
„ „	19,200	43,032	44·6	15·1	0·26	14·1
„ „	16,100	44,448	36·2	31·9	0·98	33·4
„ „	13,400	36,044	37·2	19·9	1·52	16·5
„ „	11,800	24,988	47·2	13·4	5·13	11·1
„ „	10,700	34,024	31·5	23·0	3·06	17·4
Ordinary bronze	19,700	29,534	66·7	8·4	0·18	4·0
„ „	19,600	27,376	71·6	5·0	0·18	2·6
„ „	17,800	22,592	78·7	5·0	0·72	2·3
„ „	17,700	21,946	80·7	3·3	0·50	1·6
„ „	17,600	20,482	85·9	1·5	0·68	1·2
„ „	16,400	20,296	80·8	3·3	1·10	1·7
Brass	10,100	27,518	36·7	18·3	5·80	16·1

TABLE II.

RESULTS OF EXPERIMENTS TO ASCERTAIN THE TENSILE STRENGTH AND THE RESISTANCE TO TORSION OF VARIOUS WIRES.

Description.	Pulling Stress. Wires as Drawn.				Twists in 5 Inches.	
	Diameter.	Area.	Stress.		As Drawn.	Annealed.
			Total.	Per Square Inch.	Mean of Three.	Mean of Three.
	inch	sq. inch	lb.	lb.	twists	twists
Phosphor-bronze	0·0655	0·003367	340	100,980	5·0	91
" "	0·0640	0·003216	389	120,957	22·3	52
" "	0·0600	0·002827	352	124,313	7·0	87
" "	0·0610	0·002922	379	129,705	8·3	98
" "	0·0595	0·002778	336	120,950	13·0	124
" "	0·0585	0·002655	395	147,113	7·5	97
" "	0·0640	0·003216	513	159,515	13·3	66
Copper	0·0640	0·003216	203	63,122	86·7	96
Brass	0·0605	0·002871	233	81,156	14·7	57
Steel (ordinary)	0·0600	0·002827	342	120,976	22·4	79
Iron galvanised, best best C	0·0580	0·002643	170	64,321	26·0	44
" " best charcoal E	0·0580	0·002643	174	65,834	48·0	87

TABLE III.

RESULTS OBTAINED WITH VARIOUS AXLE-BEARINGS.

Nature of Bearing.	Composition in 100 Parts Alloy.	Comparative Cost of 100 Kilos. Bearings inclusive of Melting Expenses, Loss, &c.	1 Kilo. Bearing Metal Runs.			Cost of Bearing Metal per Waggon with 4 Bearings per 100 Kilometres.	Names of Railroads where used.
			German Miles.	Kilometres.	Wear per 100 Kilos. for 4 Bearings.		
		marks			grammes	sp. gr.	
Gun metal	83 copper, 17 tin	260·20	12,052	90,390	11·60	0·301	Austrian Railway.
„ „	82 „ 18 „	260·80	13,320	99,900	10·01	0·260	Grand Central Belge.
White metal	3 „ 90 „ 7 antimony	298·68	9,104	78,280	14·64	0·395	Austrian Railway.
„ „	5 „ 85 „ 10 „	293·40	11,750	88,145	11·35	0·331	Niederschlesisch-Markische Bahn.
Lead composition ..	84 lead, 16 antimony	118·56	10,338	81,280	12·30	0·145	Austrian Railway.
Phosphor bronze ..	—	350·00	57,226	429,200	2·33	0·081	Grand Central Belge.
Gun-metal on brake cars	82 copper, 18 tin	260·80	1,218	9,134	109·48	2·844	„ „ „
Phosphor bronze on brake cars	—	350·00	14,320	107,410	9·31	0·325	„ „ „

Silicium Bronze.

We come in the next place to silicium bronze, which in some respects may be considered as an outcome of phosphor bronze, although its invention is not due to Dr. Künzel, who died some years ago. The inventor is M. Lazare Weiller, of Angoulême, who exhibited phosphor-bronze telegraphic and telephonic conductors at the Paris Electrical Exhibition of 1881, where the author first saw them, and where they were novelties. M. Weiller carried out an exhaustive series of experiments with this wire, the results of which went to show that it possessed a conductivity one-third that of copper, but two and a half times that of iron and steel. Phosphor-bronze wires, therefore, proved very useful for telephonic communication, but not for telegraphic purposes, where higher conductivity is required. M. Weiller, therefore, set himself the task of discovering a material analogous to phosphor bronze, and his labours were at length crowned with success by the discovery of silicium bronze. In this alloy the phosphorus is replaced by a silicious metalloid which produces a better conductor than does phosphorus. M. Weiller thus obtains a wire presenting the same resistance to rupture as phosphor-bronze wire, but with a much higher degree of conductivity, rendering it applicable for telegraph lines, and bringing the valuable qualities of lightness and non-oxidisability within easy and economical reach. In a paper upon electrical conductors, read by Mr. W. H. Preece, F.R.S., before the Institution of Civil Engineers, in December 1883, that gentleman observed in reference to phosphor- and silicium-bronze wires that in their manufacture phosphorus and silicium had the property of removing impurities, particularly the oxides, though doubtless some of the flux remained. Phosphorus had a most injurious influence on the electrical resistance of the alloy. Silicium was far superior; hence the silicium bronze was preferable for telegraphic purposes. Its efficiency was very great; in fact, phosphor bronze had disappeared for telegraph wire, and had been replaced by silicium bronze. It is important to note that the properties of this alloy are such that, although the wires are only one-tenth as heavy as the ordinary wires, they are of equal strength. Moreover, it is affirmed that, if broken, they will not fall to the ground as the ordinary wires do, but by reason of their high elasticity they will spring back and coil up close to the standards. The author should mention that M. Weiller had associated himself with the Phosphor Bronze Company, who are manufacturing silicium-bronze wire, which, the author is informed, has come largely into use for

overhead telephone lines, and proves a satisfactory substitute for the cumbrous iron wire. Table IV. shows the relative strength, resistance, and conductivity of various wires.

TABLE IV.

Description of Wire.	Tensile Strength per Square Inch in Tons.	Resistance per Mile in Ohms.	Relative Conductivity.
Pure copper	17·78	33·1	100
Silicium bronze (telegraph)	28·57	34·5	96
„ „ (telephone)	48·25	103·0	34
Phosphor bronze (telephone)	45·71	124·0	26
Swedish galvanised iron	22·86	216.0	16
Galvanised Bessemer steel	25·40	249·0	13
Siemens-Martin steel	26·67	266·0	12

Manganese Bronze.

The author now comes to that class of bronzes into the composition of which iron in one form or other enters, and of which there are two principal varieties, namely, manganese bronze and delta metal. It is stated that some of the ancient bronzes have been found on analysis to contain a small percentage of iron, but it does not appear that any traces of manganese have ever been discovered. It is thought probable that the ancients knew that the addition of iron to bronze would increase its hardness, and introduced it for that purpose. Modern inventors have proposed combinations of iron with brass alloys, and some have also introduced manganese by reducing the black oxide of manganese and combining it with the copper. Until a comparatively recent date, however, none of these alloys appear to have been brought into permanent practical use. More than a hundred years since, James Kier proposed an alloy of 10 parts of iron with 100 parts of copper and 75 parts of zinc, and in later times Sir John Anderson, when superintendent of the Royal Gun Factories, carried out a number of experiments with similar alloys, and with some very good results, but none of them appear to have been brought into practical use. The addition of iron unquestionably increases the strength and hardness of these alloys, but according to some experiments made by Mr. P. M. Parsons, they would appear to acquire these qualities at the expense of ductility and toughness, and it is probably on this account that this class of alloys had not come into general use up to the time of Mr. Parsons' experiments. Mr. Alexander Parkes and

the late Mr. J. D. Morries Stirling, both eminent metallurgists, appear to have been the first to propose and to carry into practice the use of manganese. Mr. Parkes combined manganese alone with copper, and used this alloy to form improved alloys of brass and yellow metal, of which to make sheathing, rods, wire, nails, and tubes.

Mr. Stirling in 1848 proposed to use manganese in various brass alloys in which iron was present. At first he combined about 7 per cent. of iron with the zinc, and added to the copper a small percentage of manganese, by reducing the black oxide of manganese with the copper in the presence of carbonaceous materials, and then added to it the requisite quantity of the iron and zinc alloy to make the improved brass required. Mr. Stirling's idea was to combine the iron with the zinc by fusion, but in practice he found a more ready means of procuring the zinc and iron alloy, by employing the deposit found at the bottom of the tanks containing the melted zinc for galvanising iron articles. This product consists of zinc with from 4 to 6 per cent. of iron, but this percentage is very variable, and the results of its use, therefore, in some cases unreliable. The author is informed that metal made by this process was in use for some time for carriage bearings on the London and North Western and other railways, with verygood results; but it has long since been superseded, and does not appear to have ever been introduced for any purposes where the requirements were great strength, hardness, and ductility.

The time, however, arrived, namely in 1876, when these requirements were met by the aid of manganese, in the manganese bronze of Mr. P. M. Parsons. This alloy is prepared by mixing a small proportion of ferro-manganese with copper, and which is afterwards made into alloys similar to gun-metal, bronze, brass, or any other alloy of which copper forms the base. The ferro-manganese is melted in a separate crucible, and is added to the copper when in a melted state. The effect of this combination is similar to that produced by the addition of ferro-manganese to the decarburised iron in a Bessemer converter. The manganese in a metallic state, having a great affinity for oxygen, cleanses the copper of any oxides it may contain by combining with them and rising to the surface in the form of slag, which renders the metal dense and homogeneous, as already explained by the author in respect of phosphorus. According to Mr. Parsons, a portion of the manganese is utilised in this manner, and the remainder, with the iron, becomes permanently combined with the copper, and plays an important part in improving and modifying the quality of the bronze and brass alloys afterwards prepared from the

copper thus treated. The effect is greatly to increase their strength, hardness, and toughness, the degrees of all of which can be modified, according to the quantity of the ferro-manganese, used and the proportions of the iron and manganese it contains.

It will thus be seen that Mr. Parsons' method of making manganese bronze is altogether different, both in principle and effect, from the inventions of either Parkes or Stirling. Stirling's method of combining the iron with the zinc, in order to introduce it into the alloys, precludes its use in any but those alloys in which a considerable portion of zinc is employed, such as brass or yellow metal. It could not be applied to any of those important alloys, of the nature of gun-metal or bronze, in which copper and tin are the chief ingredients. An equally important difference in the manufacture of manganese bronze consists in adding the manganese in its metallic state, in the form of ferro-manganese, to the copper, by which the copper is cleansed from oxides, which it cannot be when the manganese is reduced from the black oxide and combined with the copper by one and the same operation, as was done by Parkes and Stirling. Another point of importance is the great nicety with which both the iron and manganese can be adjusted, and their effect controlled, by adding the ferro-manganese to the copper, as pursued in the manufacture of manganese bronze. The amount of manganese required for deoxidising the copper, and for permanent combination with it, being well known by experience, it is found that very slight variations in quantity have a perceptible and ascertained effect in modifying the qualities of the alloys produced. The toughness can be increased, and the hardness diminished, or vice versâ, at will, precisely as is done in the manufacture of steel, by increasing or diminishing the percentage of carbon and manganese. In preparing the ferro-manganese for use, Mr. Parsons prefers that which is rich in manganese, containing from 50 to 60 per cent. This is melted with a certain proportion of the best wrought-iron scrap, so as to bring down the manganese to the various proportions required. At the same time any silicon it contains is reduced and the metal refined. About four qualities of ferro-manganese are made in practice, containing from about 10 to 40 per cent. of metallic manganese. The lower qualities are used for those copper alloys in which the zinc exceeds the tin, and the higher qualities for those in which tin is used alone, or exceeds the zinc used in combination; and the amount of ferro-manganese added varies generally from about 2 to 4 per cent. After a number of careful experiments and crucial tests, the Manganese

Bronze and Brass Company, who are the sole manufacturers of manganese bronze, adopted the manufacture of five different qualities of this alloy, although other varieties can be produced for special purposes. In No. 1 quality the zinc alloyed with the copper is considerably in excess of the tin. It is cast into ingots in metal moulds, and then forged, rolled, or worked hot, and made into rods, plates, sheets, sheathing, and it may also be worked cold, and drawn into tubes and wire. When simply cast, it is stated to possess a tensile strength of about 24 tons per square inch, with an elastic limit of from 14 to 15 tons. When rolled into rods or plates, it has a tensile strength of from 28 to 32 tons, with a limit of 15 to 23 tons per square inch, and it stretches from 20 to 45 per cent. of its length before breaking. When rolled cold, the elastic limit rises to over 30 tons, and the breaking strength to about 40 tons, and it still elongates about 12 per cent. before breaking.

Manganese bronze No. 2 is similar to No. 1, but stronger, and it can be cast in sand for special purposes where strength, hardness, and toughness are required. But it must be melted in crucibles, as passing it through the reverberatory furnace injures the metal and causes unsound castings. It is not, therefore, adapted for general brassfounders' purposes. One of the most important applications of this quality is that of producing articles cast in metal moulds under pressure. Blocks of this metal thus simply cast are said to have all the characteristics of forged steel as regards strength, toughness, and hardness, without any of its defects. It is perfectly homogeneous, and while not possessing a fibrous texture derived from rolling or hammering, it is still fibrous in character, and this in not one but in all directions alike, and, when broken, shows a beautiful silky fracture. Its tensile strength is from 32 tons to 35 tons per square inch, and its elastic limit from 16 to 22 tons, with an ultimate elongation of from 12 to 22 per cent.

Another feature of No. 2 quality is that it can be cast on to any object, and will shrink on to it with a force equal to its elastic limit, and, when released, will show an amount of resilience of about double that of steel. As an instance of this, the author is informed that a hoop of this manganese bronze, shrunk on to a solid cylinder of iron, stretched, when hot, 0·03 of its diameter in the process of contraction, and, when cold and released, sprang back about 0·003 of its diameter. As regards hardness, it is about equal to mild steel. In order to ascertain its efficiency in this respect, and to compare it with gun-metal, wrought iron, and steel, a knife-edged angular die was forced into the flat surface of a piece each of these metals and of the No. 2 manganese bronze cast

under pressure. In order to produce an indentation of equal depth in each of these specimens, the following pressures are required:—

Gun-metal	12 cwt.
Wrought iron	15 „
Mild steel	20 „
„ „ oil-hardened	25 „
Manganese bronze as cast	20 „
„ „ hardened by pressure ..	22–23 „

These results point to this material as the most suitable for the construction of hydraulic and other cylinders required to stand great strains, and possibly for ordnance. No. 3 quality is composed principally of copper and tin in about the same proportions as gun-metal, combined with a large percentage of ferro-manganese. Its chief characteristics are great transverse strength, toughness, and hardness, the facility with which it can be cast, and the soundness and uniformity of the castings produced. It will stand melting in an ordinary reverberatory furnace without injury to the metal, which is a point of importance in producing large castings. The author is informed that a bar of this metal cast in sand in the ordinary way, 1 inch square, placed on supports 12 inches apart, requires upwards of 4200 lb. to break it, and before breaking it will bend to a right angle, and it will sustain from 1700 to 1800 lb. before taking a permanent set. This quality of manganese bronze is used for wheel gearing, supports and connections of machines, crank-pin brasses, the shells of main and other bearings of marine and other engines, axle-boxes, and other parts of locomotive engines. It is also adapted for statuary and art purposes generally, as well as for large bells.

The most important application of this quality of manganese bronze from a commercial point of view would appear to be that of screw-propellers. Owing to the great strength of this quality of the metal, and its non-liability to corrosion, propeller blades can be made thinner than even those of steel. Their surfaces are very smooth, and, when cast, they are said to be theoretically true to form, whereas with steel propellers allowance has to be made against the corrosion which takes place and their deficiency in toughness, by increasing their thickness, and their form is liable to become distorted in the annealing-oven they have to pass through after being cast. The author is informed that it has been proved conclusively by the logs of steamships which have had their steel propellers replaced by manganese-bronze blades that their speed has been increased, and the consumption of coal diminished, whilst

the vibration and strain on the ship and machinery have been reduced. The commercial bearing of the question alluded to by the author is that these advantages are secured at a considerably less ultimate cost than by the use of steel, taking it upon the average life of a vessel; for although the first cost of a propeller with manganese-bronze blades is double that of steel, it is said to be practically indestructible, whereas at the end of about three years steel blades become so corroded that they have to be renewed, which brings up the total cost of the steel blades on an average to two or three times those of manganese bronze. That these propellers are incorrodible, and in every other respect efficient, is said to be proved by experience, as some have been at work for nearly four years and are as perfect as when first applied.

The soundness and tenacity of the No. 3 quality of manganese bronze thus applied was demonstrated by an accident which occurred to the propeller of the *Garth Castle*, on its launch from the yard of Messrs. John Elder and Co., in 1880. One of the blades came in contact with the jetty, and was bent round without a crack to nearly a right angle, and was afterwards hammered back cold to its original form without detriment. Another example is afforded by the propeller of the North German Lloyd's steamship *Mosel*, which was wrecked. One of the propeller blades, after it was recovered from the wreck, was found to be completely doubled over, thus affording an idea of the tenacity of the metal.

With regard to Nos. 4 and 5 qualities of manganese bronze, the author has only to observe that they have no particular claim to strength, but are effectively used for bearings, slide-valves, slide-blocks, piston-rings, and, in fact, wherever friction occurs.

Table V. shows the results of some tensile tests applied to eleven specimens of manganese bronze. The tests in the first series were made at the Royal Gun Factories, and at University College, London, respectively. Those in the second series were made at the Royal Gun Factories, whilst those in the third series were made by the Manganese Bronze Company. The specimens tested at the Royal Gun Factory were 2 inches in length, whilst those tested at University College, and by the company, were 8 inches in length. It is to be observed with reference to the last two samples that No. 10 was cut from the side of the ingot, whilst No. 11 was taken from the centre. The ingot shows a higher quality on its exterior, which indi-

ca itability for guns, where the interior would be bored

a Manganese Bronze Company are, in fact, now

n castings for artillery.

TABLE V.

TESTS OF MANGANESE BRONZE BY TENSILE STRAIN.

No.	Description.	Where tested.	Elastic Limit.	Breaking Strain.	Ultimate Elongation.	Remarks.
			tons per sq. in.	tons per sq. in.	per cent.	
1	No. 1 rods rolled hot	R. G. F.	11·00	29·00	44·6	Mild, annealed for riveting cold.
2		U. C. L.	13·17	29·29	33·4	Annealed.
3		Do.	23·54	31·60	26·5	As delivered from the rolls.
4		Do.	24·32	31·43	23·3	
5		R. G. F.	34·40	39·60	11·6	Ditto, and finished cold.
6	No. 1 plates rolled hot	R. G. F.	14·06	28·46	23·2	Pulled across fibre. Annealed.
7		Do.	14·06	30·13	47·8	Pulled with fibre.
8		Do.	14·80	30·78	34·1	Pulled across fibre.
9		Do.	16·70	30·10	28·8	Pulled with fibre.
10	No. 2 cast under pressure	M. B. & B. Co.	18·00	35·00	22·0	Cast in an iron cylinder and pressed while liquid.
11		Do.	16·23	31·90	12·4	

No. 10 cut from side of ingot, and No. 11 from centre.

Table VI. gives the results of the tests of four 8-inch samples of manganese bronze by torsion at University College. With respect to these, it is to be observed that sample No. 3 was removed from the machine unbroken, whilst No. 4 was broken and showed a clean shear.

Table VII. shows the results of the tests of a bar of manganese bronze No. 3 by transverse strain. The bar was 1 inch square, cast in sand, and placed on supports with 12-inch bearings, a steady pressure being applied on the bar at the centre.

Table VIII. shows the results of some experiments on the transverse strength and toughness of bars of manganese bronze, as compared with wrought iron and gun-metal. In these tests a weight of 50 lb. was dropped from a height of 5 feet on to the middle of the bar carried on supports with 12-inch bearings. The bars were each 1 inch square and 14½ inches long. The specimens of gun-metal Nos. 1, 2 and 3 were sent from the locomotive works of one of our leading railways, and were tested in the presence of an officer of the department, and the author believes they fairly represent the qualities of gun-metal ordinarily found in such works and supplied by brass-founders. Nos. 4 and 5 were cast specially, and were composed of 16 parts of best selected copper and 2 parts of English tin. No. 6 was composed of 16 parts of copper and 2½ parts of tin by weight.

Delta Metal.

The second and latest example of the successful addition of iron to bronze is afforded by delta metal, which was brought out by Mr. Alexander Dick in 1883. And here it may be as well if the author explains how this alloy came to receive its name. He does so because it was one of the first inquiries he addressed to the inventor, and because he has several times been asked the question, and if the invention had any reference to the delta of rivers. The author need hardly say that it has no such reference. The name "delta" was given to it by Mr. Dick simply for the purpose of connecting it with his own name, delta being the Greek for the letter D, the initial of the inventor's surname. In his researches and early experiments, and, in fact, in the development of delta metal into practical form, Mr. Dick was influenced by the circumstance that some twenty years since Aich and Baron Rosthorn, of Vienna, introduced a small percentage of iron into copper-zinc alloys, with the view of improving the same. The results obtained, which are tabulated by Dr. Percy in his work on 'Iron and Steel,' show that the alloys possessed very remarkable strength and tenacity,

TABLE VI.

TESTS OF MANGANESE BRONZE BY TORSION.

	Description.	Where Tested.	Diameter.	Twisting Moments.		Amount of Twist in Length of One Diameter.	Remarks.
				Elastic Limit.	Breaking Strain.		
			inch.	inch-lb.	inch-lb.	No. of turns.	
1	No. 2 cast under pressure	U. C. L.	0·622	1170	3360	0·183	Uniform twist.
2		Do.	0·624	1200	3372	0·166	Do.
3	No. 1 rolled	Do.	0·621	1110	2880	0·175	Annealed.
4	Rod	Do.	0·621	1980	3242	0·165	Rolled hot, and tested as it came from rolls.

No. 3 was removed from machine unbroken. No. 4 was broken, showing a clean shear.

TABLE VII.

TEST OF A BAR OF MANGANESE BRONZE No. 3 BY TRANSVERSE STRAIN.

(Bar 1 inch square, cast in sand, placed on supports 12 inches apart; steady pressure applied in middle of bar.)

Strain.	Deflection, Strain on.	Permanent Set, Strain off.	Strain.	Deflection, Strain on.	Permanent Set, Strain off.
lb.	inch.	inch.	lb.	inch.	inch.
896	0·025	—	2688	0·21	0·12
1120	0·03	—	3136	0·44	0·34
1344	0·04	—	3584	0·86	0·73
1568	0·045	—	4032	1·62	1·44
1792	0·06	0·005*	4144	1·97	—
1904	0·065	0·01*	4256	Gave way without breaking, and bent to a right angle.	

* Elastic Limit.

TABLE VIII.

EXPERIMENTS ON THE TRANSVERSE STRENGTH AND TOUGHNESS OF BARS OF MANGANESE BRONZE AS COMPARED WITH WROUGHT IRON AND GUN-METAL, MADE BY DROPPING A WEIGHT ON THE MIDDLE OF THE BAR RESTING ON SUPPORTS AT EACH END.

(Weight of monkey, 50 lb.; height of fall, 5 feet; distance between supports, 1 foot; dimensions of bar, 1 inch square, 14½ inches long.)

No. of Blows.	Permanent Deflection in Inches, in the Length of 12 Inches.										
	Wrought Iron.		Gun Metal.						Manganese Bronze.			
	Staffordshire Rolled.		Cast in Sand.						No. 3, Cast in Sand.		No. 1, Forged.	
	No. 1.	No. 2.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 3.	No. 4.	No. 5.	No. 6.
1	0·57	0·58	0·82	0·86	0·90	0·72	0·73	0·46	0·66	0·60	0·59	0·60
2	1·10	1·15	1·50	1·58	1·63	1·32	1·42	and	1·20	1·15	1·06	1·08
3	1·62	1·71	1·70	2·22	2·35	1·92	1·52	broke	1·70	1·60	1·44	1·50
4	2·13	2·23	and	and	2·86	1·94	and	—	2·23	2·07	1·80	1·89
5	2·65	2·77	broke	broke	and	and	broke	—	2·67	2·52	2·12	2·26
6	3·19	3·37	—	—	broke	broke	—	—	3·11	2·97	2·45	2·65
7	3·77	3·99	—	—	—	—	—	—	3·58	3·39	2·77	2·99
8	4·39	4·63	—	—	—	—	—	—	4·02	4·04	3·05	3·38
9	not broken		—	—	—	—	—	—	not	and	3·33	not
10			—	—	—	—	—	—	broken	broke	not	broken
11			—	—	—	—	—	—	—	half	broken	—
12			—	—	—	—	—	—	—	through	—	—
13			—	—	—	—	—	—	—	—	—	—

and it seemed strange to Mr. Dick that, having such valuable qualities, they did not come into general use. A London brass-founder, who used to manufacture these alloys, informed Mr. Dick that at times he obtained excellent results with bearings and other parts of machinery made therewith, and then again the results were the very reverse, in spite of his taking the greatest care in manufacturing, as he thought, in identically the same way. Unable to account for the different results, he and several other manufacturers were obliged to abandon these alloys in spite of their promising features.

Mr. Dick endeavoured to ascertain the cause of the uncertainty of these results, and he produced various quantities of the alloys, apparently in exactly the same way, by dissolving wrought iron in molten copper according to the Austrian method. The qualities of the resulting alloys, however, varied very much, simply because the amount of iron dissolved varied in each parcel. His first object, therefore, was to find a method by which he was enabled to introduce a known and definite quantity of iron, which he succeeded in doing by dissolving the iron in molten zinc to saturation, and adding the same, with or without pure zinc, to the molten copper. The desired quantity of iron can be introduced with great nicety. In consequence of the metals partly oxidising during the process of remelting, the castings, however, again varied in character, the oxides being dissolved in the alloy and destroying its tenacity and strength. This second difficulty was overcome by adding a small percentage of phosphorus in combination with copper. In some cases Mr. Dick also introduces tin, manganese, or lead into the alloy, to impart special qualities to it. By a series of experiments the most useful combinations were then ascertained, and alloys of definite compositions, and possessing special and very valuable qualities, are now produced under the name of delta metal.

The specific gravity of delta metal is 8·4, its melting-point 1800°. In colour it resembles gold alloyed with silver. It can be worked hot and cold. When melted, it runs freely, and the castings produced from it are sound and of a fine close grain. Like all copper alloys, it does not weld, but can be brazed like copper or brass, and if the object is of sufficient thickness, it can be "burned" with great facility. Cast in sand, it has a breaking strain of over 21 tons per square inch. When forged at a dark red heat, the breaking strain is raised to from 33 to 35 tons, and when hammered or rolled cold, it will stand a strain of more than 40 tons per square inch. The varieties destined for working cold can be drawn into tubes and wire, or rolled into sheets and rods, whilst those intended for working hot, not

only can be rolled with great facility when heated to about 1600° Fahr., but are also capable of being stamped or punched, similarly to wrought iron and steel, into a great variety of articles which have hitherto been cast in bronze or brass. The author would draw special attention to this quality of delta metal, as the possibility of hot stamping offers great advantages over castings—the articles are turned out much cheaper, they are of perfect soundness, and possess three times the strength of brass castings. Blowholes, which frequently can only be detected after expending time and labour, are impossible, besides which a great saving is effected in the finishing of such articles, as, unlike castings, the stampings leave the die almost perfect, requiring little or no tooling, but ready to be polished. Experiments are being made at the present time to utilise the semi-plastic state of heated delta metal to press it by hydraulic pressure into tubes and rods of round, hexagonal, and other sections in a way similar to that in which lead tubes are pressed.

It is interesting to know that the iron introduced by Mr. Dick's process is really chemically combined. This is proved by the alloy not rusting when exposed to the moist atmosphere, and also by its having no influence whatever on the magnetic needle. Experiments have shown that by suspending a piece of delta metal on a thread, and at various angles between the ends of a powerful electro-magnet, no oscillations of the suspended metal could be observed, which evidently proved that the iron contained therein had lost its magnetic properties.

The uses to which delta metal can be applied are very numerous. It is said to replace the best brass and gun-metal with advantage, and in many instances iron and steel also, as it does not corrode or rust. Thus, parts of rifles, of guns, of torpedoes, tools for gunpowder mills, parts of bicycles, gongs, and a number of domestic articles, are now stamped in delta instead of steel; while spindles for steam and water valves, plungers, and pump-rods are forged in the same metal. In the International Exhibition at the Crystal Palace may be seen a steam launch constructed throughout of delta metal by Messrs. A. F. Yarrow & Co. This launch is 36 feet long over all, with a beam of 5 feet 6 inches, and a depth from gunwale to keel of 3 feet. Delta metal having been proved by experiment to be equal in strength, ductility, and toughness to mild steel, the plates and angle-pieces of the launch are of the same scantling as they would be if steel were used, viz. $\frac{3}{32}$-inch thick. The stern, ke[illegible] sternposts are of forged delta metal, and scraped toge[illegible]s usually done. The angle-frames are made of th[illegible]erial, but are placed longitudinally

instead of transversely, by which means greater longitudinal strength is secured. The propeller, which is cast in delta metal, is four-bladed, 2 feet 4 inches in diameter, and 3 feet pitch. The engine is of the usual direct-acting inverted type, of sufficient power to develop a speed of from eight to nine knots per hour. The superiority which delta metal possesses over steel and iron for ship-building is that it does not rust like they do. Such launches are specially adapted for the transport of salt, sugar, and chemicals, which rapidly corrode steel. The extra first cost would probably be quickly repaid, besides which the metal always retains its value.

In Table IX. are given the results of some experiments made at the Imperial Testing-house, Berlin, on May 28th and June 4th, 1884, to test the tensile, torsional, and crushing strength of delta metal. Table X. shows the result of a test of a cast delta metal chain. From these tables it will be seen that the elastic limit of the delta metal is 31,571 lb., or 14·1 tons per square inch. The commencement of permanent set took place at 49,757 lb., equal to 22·2 tons per square inch. The breaking strain per square inch was 80,658 lb., equal to 37·34 tons; the elongation was 12·9 per cent., and the contraction of area of fracture 17·4 per cent. The crushing test, with a stress of 22,000 lb., gave 0·80 per cent. of compression; 44,000 lb., 1·33 per cent.; 66,000 lb., 2·03 per cent.; 77,000 lb., 2·71 per cent.; 88,000 lb., 3·87 per cent.; 99,000 lb., 5·77 per cent.; 110,000 lb., 8·20 per cent.; 121,000 lb., 10·76 per cent.; and 132,000 lb., 13·41 per cent. The ultimate or crushing stress per square inch was 135,700 lb. equal to 60·5 tons. In the torsional tests the sample was 10 inches long, and it will be seen that it was twisted more than twice round, the torsion being registered in degrees. The chain tested (the results of which are given in Table X.) was a portion of one of those supplied to the Brazilian armour-clad turret-ship *Riachuelo*. The length tested was 10 feet, the links being 0·733 inch in diameter, and the length giving way under a stress equal to 19·3 tons per square inch.

Phosphor Copper.

We have now done with the modern bronzes of what the author may call the primary series, and have reached those which may be considered as forming a secondary series, in the sense that several of them are more or less but modifications, combinations, or adaptations of those previously described. The author has already referred to the beneficial effect of phosphorus on copper and its alloys, and which consists in producing

TABLE IX.

EXPERIMENTS WITH ROLLED ROUND BAR OF DELTA METAL TO ASCERTAIN THE TENSILE, CRUSHING, AND TORSIONAL STRENGTH.

TENSILE TEST.

Original Diameter.	Original Area.	Original Length.	Elastic Limit per Square Inch.	Commencement of Permanent Set per Square Inch.	Ultimate Stress per Square Inch.	Elongation.	Contraction of Area of Fracture.
sq. inch	sq. inch	inches				per cent.	per cent.
0·795	0·497	10·0	31,575 lb. = 14·1 tons	49,757 lb. = 22·2 tons	80,658 lb. = 37·34 tons	12·9	17·4

CRUSHING TEST.

Original Diameter.	Original Area.	Original Length.	Compression by a Stress of									Ultimate Stress per Square Inch.
			Lb. 22,000	Lb. 44,000	Lb. 66,000	Lb. 77,000	Lb. 88,000	Lb. 99,000	Lb. 110,000	Lb. 121,000	Lb. 132,000	
inch.	sq. in.	inch.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	lb. tons
1·19	1·11	1·19	0·80	1·33	2·03	2·71	3·87	5·77	8·20	10·76	13·41	135,700 = 60·5

TORSIONAL TEST.

(Twisting measured in degrees. Length of lever = 1 foot.)

Original Diameter.	Original Area.	Original Length.	Stress applied in lb.									
			4·137	8·274	12·41	14·48	16·45	20·686	28·961	37·235	45·51	53·78	60·0
inch	sq. inch	inches	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°	°	°	
0·394	0·1227	10·24	1 5	4 0	6 5	8 48 Elastic limit	10 0	16 5	70 0	242	486	794	Fracture.

TABLE X.

TEST OF CAST DELTA METAL CHAIN.

Description.	Stress.	Extension.		Remarks.
		Under Stress.	Permanent.	
	tons	inches	inch	
Delta metal chain cast in sand—0·733 inch diameter of link, 10 feet long.	2·176	0·07	0·01	
	2·544	0·1	0·03	Appearance of fracture — yellowish grey, close and uniform.
	2·946	0·2	0·1	
	3·381	0·3	0·25	
	3·616	0·4	0·34	
	3·870	0·5	0·43	
	4·040	0·6	0·53	
	4·285	0·7	0·62	Complete fracture at root of link (several links partly fractured).
	4·464	0·8	0·72	
	4·665	0·9	0·81	
	8·147	2·8	—	

Ultimate Stress = 19·3 tons per square inch.

a material of absolute closeness, of the highest possible degree of toughness and elasticity, or, according to the percentage of phosphorus added, the metal can be rendered soft, or as hard as steel. These excellent qualities must not be attributed alone to the phosphorus in the metal, or only in a secondary degree, but are owing chiefly to the absence of oxygen, which, by the energetic reducing action of the phosphorus, is entirely eliminated. This question having received the attention of Mr. W. G. Otto, of Darmstadt, that gentleman conceived the idea of introducing phosphorus into copper in order to facilitate the work of engineers and founders by enabling them to add a certain proportion of phosphor copper to a given bulk of metal, so as to obtain a phosphor bronze suitable for various purposes. Phosphor copper contains from 15 to 16 per cent. of phosphorus, and Mr. Otto, who is represented in England by Mr. G. Hartmann, applies this product to the purposes of producing phosphor bronze, homogeneous copper castings, and copper alloys of all classes. In practice the copper is melted in the ordinary way, as rapidly as possible, and is kept covered with charcoal. After the requisite quantity of tin, zinc, &c., has been added to the liquid metal—or if re-melting old or scrap metal, after these have been completely melted—the crucible is taken out of the furnace, and the metal carefully freed from the charcoal, &c., floating on the top, after which the small quantity of phosphor copper necessary is added whilst thoroughly stirring the metal. A skin which is found covering the liquid metal (bronzes in particular) then disappears, and the metal assumes a perfectly bright surface, which is a sign that the quantity of phosphor copper added was sufficient to remove all oxides present. The metal is then cast at once, care being taken to prevent foreign substances and any skin which may meanwhile have formed again from being poured into the moulds. The presence of a perfectly bright surface is absolutely necessary, and also careful stirring of the metal down to the bottom of the crucible, for which purpose Mr. Otto made special stirrers. With regard to the proportions to be observed, the author is informed that for producing phosphor bronze and remelting old gun-metal, an addition of from 10 to 12 oz. of phosphor copper, containing 15 per cent. of phosphorus per 100 lb. of metal, is generally sufficient, whilst for making and remelting brass and brass scrap, an addition of only 5 to 7 oz. of phosphor copper is required per 100 lb. of metal. The author understands that Otto's phosphor copper is in use at many continental government works, as well as by foreign railway companies and at private works, with every satisfaction. Without for one moment wishing to appear as questioning this, the author still adheres to the opinion already expressed, namely, that

to purchase the ingots of metal for the various required purposes already prepared by those whose sole business it is to produce them, and whose credit is at stake if an error of proportion be committed, is to his mind the more satisfactory course. He conceives it to be pitting rule of thumb against careful research and practical experience.

Phosphor-Manganese Bronze.

There is in the market a compound known as phosphor-manganese bronze, which is stated to be used for engineering purposes. The author has twice written to the producers of this alloy for information respecting its nature and uses, but without receiving a reply to either of his letters. It is, therefore, the manufacturers' misfortune, and not the author's fault, that this production is not described in the present paper. Silence, however, is said to be golden, and, looking at the compound name of the alloy in question, the adage may apply with special force in the present instance.

Phosphor-Lead Bronze.

About the middle of the year 1881 a new alloy under the name of phosphor-lead bronze was brought to the author's notice. It was stated to be specially adapted for all purposes where gun-metal, brass, or other material is used in the construction of those portions of machinery subject to constant wear or continuous friction. The introduction of lead into its composition, and its homogeneousness, were said to give it special properties, rendering it most efficacious for the purpose mentioned. It had been subjected to every test that experience could suggest, and was reported to have passed them all most satisfactorily. The advantages claimed for phosphor-lead bronze, were self-lubrication, greater wearing capacity than any other metal or alloy, great tensile strength—combined with extreme hardness—and non-liability to fracture. It was averred that it remained perfectly cool under continuous and excessive friction, and it was said to be in extensive use on the Continent by manufacturing engineers, shipbuilders, and others, with satisfactory results. It was being introduced into this country by Messrs. K. H. Kühne & Co., of Löbtau, near Dresden; but the author has not heard anything further of this alloy.

Phosphor Tin.

Under the name of phosphor tin, Messrs. Billington and Newton manufacture a compound which is used for making phosphor bronze. This compound is a mixture of phosphorus with tin in certain proportions, the metal being sold to con-

sumers who make their own phosphor bronze by adding the phosphor tin to copper. The copper is melted in a crucible, and when in a fluid state the phosphor tin is added in the same way as ordinary tin. The mixture is then well stirred with an iron rod, covered with a coating of blacklead. The metal is poured just before it begins to set in the crucible, and the moulds are always to be very dry, and where 20 per cent. of phosphor tin is used, the castings are made in chills if possible. The author has applied to the manufacturers for detail particulars and tests, but he has not been favoured with them. It will be seen that phosphor tin is used in the same way as the phosphor copper already referred to, and although the use of phosphor tin is stated to be attended with good results, the author can only repeat the opinion already expressed, that, considering what diverse effects a slight variation in proportions appears to bring about, it is better for most purposes to obtain the alloy ready prepared than to trust to workmen for obtaining uniform results. The author is aware that he may be met by the statement that successful results are daily obtained by workmen using these compounds. This is no doubt true so far as it goes, but it is no answer to his assertion that rule of thumb can never hope to compete with scientific exactitude. He could give instances in the metallurgy of iron and steel where rule-of-thumb principles held out for a long time against the advances of higher science, but to whose dictum they were in course of time compelled to bow.

Aluminium Bronze.

The history of the practical manufacture of aluminium does not extend very far back into the past; in fact, its commencement dates within the limits of the present generation. The three international exhibitions which have been held in Paris since aluminium began to be worked on a commercial scale form so many landmarks of its progress. In 1855 it was met with for the first time in the Palais de l'Industrie in the form of a large bar, and was exhibited as silver produced from clay. In the Exposition of 1867 it was to be seen in a more advanced stage, worked up into castings and various kinds of useful and ornamental articles. There also for the first time was seen the alloy aluminium bronze. The Paris Exhibition of 1878 witnessed the maturity of the aluminium manufacture and its establishment as a current industry, having a regular demand and supply for certain purposes within the limits permitted by its somewhat high price. To France, then, is due the merit of having been the first country to carry out Wöhler's process for

the production of this metal on a commercial scale, and to have created the aluminium manufacture. Until recently, moreover, France appeared to be the only country in which the trade was able to prosper. The English manufactory established at Washington, near Newcastle-on-Tyne, by Messrs. Bell and Co., did not answer, and was closed some ten years ago. The German factory started at Berlin, by Messrs. Wirtz and Co., hardly lived at all, having drooped before it was well started. In France, however, the manufacture appears to have gone steadily on from the first.

The chief obstacle which has retarded the development of the manufacture of aluminium in England appears to have been the difficulty of obtaining the metal pure, the least portion of foreign matter rendering it useless for the purpose of alloy. This circumstance, coupled with its high price, has caused its use to be very limited, although the value of aluminium alloys has long been well understood. About two years since, however, Mr. James Webster perfected his invention for producing aluminium, and which is now being practically worked. It is claimed that by his process both the objections just stated are removed, the alumina being produced in a condition of great purity, without a trace of iron, and so, by care in the succeeding stages, the aluminium itself is free from all contamination with foreign substances. In Webster's process the source of the alumina is potash alum. This is ground to powder and mixed with pitch and gas-tar, in the proportion of 8 parts of alum to 1 part of pitch and 1 part of tar. The mixture is then thrown on the bed of a reverberatory furnace and carefully heated. By this means the water only is driven off, while the sulphur and iron remain with a little carbonaceous matter in the cake. The operation requires careful attention, since, if the temperature be raised too high, burnt alum, which is unalterable, is the result. The fused mass is then removed from the furnace, and is ready for transference to the hydrate retorts. These are made of refractory fireclay, and are vertical. They are charged from the top, whilst a mixture of steam and air is blown in at the bottom. At a red heat decomposition takes place, sulphuric acid and sulphur, together with iron sulphate, being carried over mechanically by the steam, and condensed in cisterns at the rear. The alumina and potash remain behind as a white cake, which is drawn from the retorts, transferred to a large tank, and lixiviated with water. The liquor, which contains all the potash, is run off into a pan and evaporated, while the alumina is transferred to bags and allowed to dry.

The Webster process appears to be a simple and successful

one. All the by-products are regained, the potash and sulphur are extracted, the iron is thrown down as a fast and brilliant blue, and the residual sulphuric acid is concentrated for use. The alumina thus obtained is balled with charcoal and salt, made into a chloride and reduced for metal, the aluminium obtained being perfectly pure and containing no iron whatever. The process is being worked by the Aluminium Crown Metal Company, and the metal itself combines strength and lightness with elegance of appearance and general utility. The metal is of two kinds, white and yellow, the former being used for cutlery and other table requisites where silver and plated goods are now employed, and for every kind of metallic fittings, lamps, harness, and carriage furniture, chains, wire, and wire ropes, and, in fact, for every purpose where a non-oxidising bright surface is a desideratum, strength also being kept in view. The yellow metal is adapted and is stated to be used for guns, screw-propellers, engine-bearings, tubes, and all the various details of machinery where gun-metal and other alloys are now used. The metal as made is supplied in ingots to the manufacturers of the various articles indicated, who produce the finished goods for the market. It is reported to stand exceedingly well in engine-bearings, and also to give perfectly satisfactory results as applied to the manufacture of screw-propellers. The metal is made in five qualities, and each quality is made either hard or soft as may be required. Samples of aluminium bronze tested by Mr. Kirkaldy have given very high results as regards tensile strength, one specimen showing an ultimate stress of 42·4 tons per square inch of original area.

Silveroid.

This metal was introduced to public notice in the early part of the present year. It is an alloy of copper and nickel adjusted with either zinc, tin, or lead in various proportions according to the purpose for which it is intended. Beyond this, however, there is a special method of treatment at a certain point in the manufacture which is stated to be the secret of success. The result is a metal of great whiteness, brilliancy, closeness of grain, and tensile strength. It is the invention of Messrs. Henry Wiggin and Co., and it is mainly intended to take the place of alloys of the brass, bronze, and gun-metal classes, in fact of every inferior metal where colour, polish, weight, and richness of lustre are desirable. The author is informed that it is in use for machinery bearings and for all kinds of cocks, valves, and engine and boiler fittings.

Cobalt Bronze.

Since bringing out their silveroid, Messrs. Wiggin have developed another alloy, which is now being introduced under the name of cobalt bronze, and which is a whiter but slightly more expensive metal than silveroid. It is, perhaps, the more interesting of the two, because there is introduced into its composition small quantities of the metal cobalt. The malleability of cobalt in a pure metallic form has long been understood; but the author believes it was not until a few years ago that it was demonstrated by Messrs. Wiggin that it might be rolled into sheets, and wrought, like other metals, into articles of utility. Its high price, however, interfered with its production, and militated against its use. This fact induced Messrs. Wiggin to endeavour to compound an alloy in which the sterling qualities of this valuable metal could be fully represented, and which, at little more than the cost of ordinary German silver, might possess in a large degree all the attributes of the pure metal itself. Possessing, as it is said to do, many of the qualities and every appearance of metallic cobalt, it is manufactured in several qualities, the higher grades being preferable, on account of their suitability for casting purposes, their close, steel-like surface, their susceptibility of a high polish, as well as their hardness, toughness, and great tensile strength. Cobalt bronze is intended to be used for the same purposes as silveroid, especially in high-class fitting work.

The author has now fulfilled the promise made at the outset of his paper, which was to place before the Society a few facts concerning such modern bronze alloys as are being usefully employed for engineering purposes. He does not lay claim to any independent personal research or experiment upon the subject, such being precluded by the constant demands upon his time in other directions. He has consequently had to accept the results obtained by others, but he accepts them in perfect good faith. As they stand, they indicate the value and importance of the modern bronzes, and will serve as guides in the choice of a metal for a given purpose. The question of modern bronzes, however, is a very important one, and presents a wide field for scientific investigation and practical research. At the present time we are comparatively in the dark upon this subject, which has not received the careful attention at the hands of metallurgists that it deserves, and if the present paper only awakens attention to this fact it will not have been written in vain. It will be seen that the author has divided the bronzes into two classes, namely, those which come under the head of original productions, and those which he can only

consider as imitations. In thus distinguishing them, he desires to give offence to none, but he sees no way of evading what he believes to be a common-sense and equitable conclusion. In conclusion, the author will only suggest that, in selecting a material for practical use, proper regard should be had to the precise purpose the metal is required to serve, and that careful scientific preparation, based upon long experience, should be allowed to prevail against rule of thumb and a possible small saving in first cost. He would the more strongly impress this view of the case upon the Members because he well knows that, although imitation is the sincerest form of flattery, flattery usually has to be paid for by some one or other.

DISCUSSION.

Mr. HARRY OLRICK said it might aid the discussion if any of the Members would say whether they had ever seen bronze in which some substance had been used as a flux other than phosphorus or manganese. The thin piece of bronze he now produced contained 89 per cent. of copper, 10 per cent. of tin, and 1 per cent. of mercury, and it was absolutely malleable, as they could see from the thinness of the sheet. It also possessed a strength which did not seem to have been equalled in the examples of the different bronzes which Mr. Nursey had mentioned. From the tables exhibited it appeared that a rolled round bar of delta metal had a maximum strength of 37·34 tons per square inch. The mercury bronze, which was simply called malleable bronze, had been tested by Professor Kennedy, who gave as the result of his examination of a great many specimens, both of cast and of rolled metal, 43·7 tons per square inch as the breaking strain, and 8 per cent. elongation in an 8-inch piece. Some of the specimens tested showed a strength of about 50 tons per square inch. It seemed to him that the hardness of an alloy was easily obtained by the proportion of tin used, but malleability was also a very important consideration.

Professor HUNTINGTON said he had been engaged in connection with bronzes for some two or three years, and during that time he had made five or six hundred machine tests, which had been carried out with a definite object. A point which Mr. Nursey had referred to was deserving of more attention than it usually received, namely the re-melting of bronzes, and the alteration in their composition and their mechanical condition occasioned thereby. Those required careful checking by machine tests. The points which appeared to have been more particularly raised by the paper were these:—

Taking the best results which could be obtained by the various metals, for what purposes were they eminently suited? Were they eminently suited for the purposes which the manufacturers specified? Then, beyond that, could the results which the manufacturers claimed be obtained uniformly? He would leave the first point to those who were greater users of bronze than he was. With regard to the second point, the various so-called modern bronzes were not bronzes in the true sense; they were alloys, some of which contained as many as five ingredients. There were so-called bronzes which contained a very large quantity of zinc. He took it that those alloys bore to gun-metal very much the same relation which cast steel bore to cast iron. It was common knowledge that cast iron was sent about the country in the form of pig-iron wherever it might be required. But with regard to cast steel, did firms like Jessop, Vickers, Osborn, or Hadfield, and others, readily trust their metal to be sent about the country to be cast by whomsoever might get hold of it? He thought the answer was, decidedly not. Those firms would think twice before they risked their reputation by allowing their metal out of their own hands. That arose from the fact that they were private manufacturers having their reputation and their capital at stake, and were not companies. The production of cast steels had been a thing of slow growth, dating back to an early period. The modern bronzes had come into existence in comparatively recent times, mostly under the auspices of companies, who had entered into rapid competition one with another, and, as a result, had been forced to seek the most ready means of disposing of their metals to users. In order to accomplish that, they had produced them in the form of ingots which were sent out to those who wanted the metal for bearings, propellers, or what not. That practice was right enough in one way. Engineers said, "We cannot always be sending to A, B, or C, to produce our work, and then have to carry the castings long distances." But, on the other hand, one must not lose sight of the fact that those persons who had invented the metals and perfected them had a vastly superior knowledge of how to cast them than could be obtained in a short time by the users, and therefore it was not surprising that, in many cases, phosphor bronze, manganese bronze, and all the other bronzes, might have come to grief in some way or other, and that the progress of those metals had been checked to a considerable extent. He had no doubt that those metals were just as superior to gun metal as cast steel was to cast iron; but, until the various casters had acquired a greater amount of knowledge than they at present possessed, in dealing

with those metals some little mishaps must be expected from time to time. He did not for a moment say that the producers of bronzes should refuse to send their metals out. The users must rather do all they could to train the casters in the various engineering shops to a better knowledge of how to deal with them. He had not only been devising bronzes himself, but he had been testing the metals produced by others. In the case of one metal, he had tested some pieces which had been recast at some engineering works in the form of test pieces, and he had also tested some of the same metal which had not been recast, but which he had had machined up into test pieces of a similar character. He found that the metal which had been re-melted had only about one-half the strength of that which had not been re-melted, but which had been machined up in the condition in which it had been received from the makers. And yet the recast test pieces had been prepared by engineers of considerable experience, and by one of their best men.

Mr. H. YOUNG said that when the phosphor bronzes came into use his firm tried them for the casting of bearings, but it was very rarely, if ever, that they could produce a perfectly sound casting. They used sand moulds, and they cast the metal perhaps a little too hot to begin with, to ensure its running sharp. He had imagined that this would give the dross of the metal an opportunity of rising to the top of the channel; but, singular to say, where he anticipated that the casting would be the most dense, namely on the bottom or lowest surface, it was the most porous. They tried to cast spindles and other things for mill-work in this way, but they were ultimately compelled to give up their attempts. It occurred to him that the metal might be more advantageously used for statuary, and therefore he offered a firm of bronze makers to risk the labour for the casting of a statue if the firm supplying the material would send some competent person to show his men how to run the metal satisfactorily. A trial was accordingly made. The mould was about as good as could be made, and he was advised to cast the metal at rather a dead heat. Statuary castings in general were very thin, and did not run more than $\frac{3}{8}$-inch to $\frac{1}{2}$-inch in thickness, therefore it was very important that the whole surface of the mould should be covered. In this instance, the metal was cast at a temperature which he thought would cover the whole face of the mould. He found, however, that the surface was porous, and therefore he went back to what might be thought to be the old rule of thumb. In his researches, he found that perhaps the best bronze for ornamental work was similar to what had been

found upon analysis to be that which had been used for bronzes of the pre-historic period, numbers of which were now to be found in our museums. The composition of those bronzes was copper 88, with about 12 per cent. of tin. There was no better metal for ensuring a good sound casting, and for coming out sharp, and running a good distance. The sphinxes on the Thames Embankment were of that composition, and were made in one running, and he considered they compared favourably with Marochetti's lions in Trafalgar Square, each of which was in seventeen parts and built up. A very good proportion for tooling and working up was 88 to 12 parts. Metal which was to be used for artistic chasing and for art sculptures was made softer. It contained about 80 per cent. of copper, 8 of tin, and 12 of zinc. Metal of that composition was more ductile and more easily manipulated, but at the same time it was more subject to oxidation. In the case of bearings and other machinery work, he found that, as a rule, a great deal depended upon the founder, because if he had special alloys supplied in ingots, he must melt them in a crucible, and perhaps the crucible, owing to the nature of the metal, had to be covered, and then he had a difficulty in running the metal into the mould and getting a sound casting. For mechanical purposes, a metal composed of copper and tin was the most reliable, and every experienced founder could produce an alloy equal to the work in hand. A proportion of 1 of tin to 4 of copper gave a very hard metal. One of tin to 2 of copper gave a composition almost like speculum, and as brittle as sealing-wax. The proportion of tin to copper might be reduced with very good results. By that means they could obtain a tough and perfectly sound metal. Soundness was a very important thing. For example, a founder might produce an intricate set of pump-barrels of phosphor bronze, and when in the machining he took the last cut, he might come upon a honeycomb part, and the whole would be useless. If he cast it with copper and tin at a proper heat, he might make sure of having a sound casting. Copper and tin should be melted separately in crucibles, and mixed just before running into the casting. The best result as to uniformity was obtained when the metal was cast at just the right heat, and which the founder understood. If it was cast too hot, it would be found that the tin would filter up through the copper and form large uneven patches.

Mr. W. Schönheyder said there had been only a slight reference in the paper to the correct proportions that should always exist in alloys. He believed that in order to get a thoroughly sound casting, whether from copper and tin or from

any other mixture, the metals must be mixed in such proportions that they would combine chemically and not merely mechanically. He believed that in ninety-nine castings out of a hundred the metals were merely mechanically combined by careful stirring, but if they were combined in their chemical proportions, a sound metal would always be obtained. Upon comparing mixtures of metals which, as he had been told by founders, made exceedingly good castings, he had found that the proportions of the metals corresponded very nearly with their relative atomic weights. It seemed to him that a necessary operation in testing the various bronzes with regard to their suitability for bearings for railway-carriages was to find out the coefficient of friction under which they ran. The amount of metal worn away might be small, and yet it might cause a great frictional resistance, and necessitate a high tractive power to propel the carriage. Generally, the amount of friction was entirely left out of consideration.

Mr. J. FARQUHARSON said he believed that he was making phosphor bronze before it was worked by the Phosphor Bronze Company, and by a different process. His experience was quite different from that of Mr. Young, who said he could not make sound castings with it. He (Mr. Farquharson) had found that phosphor bronze was the most easily managed of all the bronzes with regard to soundness. Strength and ductility of course varied according to the proportions in which the ingredients were used, but he had never found any difficulty in getting perfectly sound castings. From what had been stated in the paper it appeared that phosphor bronze was now made from quite a different phosphide from that which was used when he first made its acquaintance. It was then made from phosphide of tin. He believed that he was the first to make the copper phosphide. He was very much surprised to find that the copper phosphide was being made with 14 per cent. of phosphorus. He had experimented to find what proportions of phosphorus would give the most economical combination, and he had come to the conclusion that about 6 or 7 per cent. was as much as could be combined without an undue loss of phosphorus. That amount could be combined with a loss of rather less than one-sixth of the phosphorus which was put in, but he should hardly be prepared to expect that a 14 per cent. combination could be made upon any such terms. He first entered into the question of using phosphorus in connection with copper for the purpose of improving its quality in the refinery; and until th e of the mill recently the Government had used is instead of the poll for all the copper that was rolled s purposes at the Royal mills at Chatham. It was

used for the purpose of reducing the amount of oxide and giving a better quality of copper. They used only such an amount of copper phosphide as would effect the purpose without leaving any phosphorus in the copper afterwards, about 1 cwt. of the phosphide to a charge of 5 tons of copper being sufficient. His experience was quite in accordance with the facts stated in Mr. Nursey's paper with regard to phosphor bronzes. So far as he had seen, the phosphor bronzes were very much more certain and uniform in their results than any of the other so-called bronzes. One remark in the paper which was well worthy of attention was, that persons intending to use the bronzes should not trust to their own way of making them, but should obtain ingots of the metal from people who knew how to make it. He would go a step farther and say, as regards manganese bronze, that if they were to get anything like the results which were shown in the tables he should advise them to get, not the ingots, but the articles themselves. He believed that he was present at the testing of some of the specimens of manganese bronze which were recorded in one of the tables. Those specimens gave very high results indeed. He had the specimens very carefully assayed by two persons eminently qualified for such work; and he obtained ingots of the same composition, made by the company, but he could never get anything like the results which were obtained from the test-pieces. He wished he could get such results in ordinary castings from the manganese bronze, but he had never seen anything like them. But in the case of the phosphor bronze which he had ordinarily used he got results very similar to those stated, and that without much difficulty. He had had very little experience of delta metal. It was a newer alloy than either of the others. He could not say much about the certainty of the results obtained with it. He had got some of the metal from Mr. Dick, but the results he obtained were not so good as those which Mr. Dick got recently. Both in manganese bronze and in delta metal, he had found considerable uncertainty as to the soundness of the castings. He thought that unless engineers could be supplied with materials which ordinary foundrymen could use, they would hardly venture to do much with them.

Mr. H. H. Lewis, alluding to the question of the suitability of phosphor bronze for friction at a high velocity and under heavy loads, said that he had had a little experience of the use of that material for worm-gearing. With a load of 7 tons on a cast-iron wheel with a steel worm, the steel wore out the cast-iron in a few weeks. He substituted a phosphor-bronze worm, and that had been running for three years. In another

instance an 8-horsepower gas-engine was driving a worm-gear crab with a steel wheel and a steel worm, and it had great difficulty in lifting 11 cwt. at a certain speed. After substituting a phosphor-bronze worm for the steel one they lifted a 20-ton load easily at the same speed.

Mr. P. M. PARSONS said he should like to know upon what experience Mr. Farquharson based the statements he had made with reference to manganese bronze.

Mr. FARQUHARSON said that the general statement which he had made about manganese bronze was that as compared with phosphor bronze it was more difficult to run sound. The Admiralty, as Mr. Parsons was aware, had some samples of manganese bronze which satisfactorily stood the high tests mentioned in Mr. Nursey's paper, but they (the Admiralty) could never make any metal approach to anything like such a strength. In order to assure themselves that there was nothing wrong they obtained from Keats and Co. a sample of copper already alloyed with 20 per cent. of manganese so that they might know precisely the quantity of manganese they were using. They used that alloy in various proportions from a very small quantity up to one which was positively injurious, and which was not a very large quantity after all; but whatever proportion of the alloy was used the Admiralty could never reach the soundness which they could obtain easily with ordinary gun-metal, or phosphor bronze; nor could they obtain the strength or ductility corresponding with the tests made by Mr. Parsons himself.

Mr. PARSONS said it was evident from what Mr. Farquharson had said, that the manganese bronze which the Admiralty made was not what was made by the company which he represented, it being alloyed with manganese alone, whereas the manganese bronze made by his (Mr. Parson's) company was alloyed with ferro-manganese, which fully accounted for the difference. There was no doubt that one of the qualities of their bronze would be difficult for an ordinary brassfounder to cast, because it required a special knowledge of the metal, and a treatment which they had found out by experience. When it received that treatment there was not the slightest difficulty in making perfectly sound castings. The tests to which Mr. Farquharson had alluded were made for the purpose of ascertaining what greater strength was possessed by the manganese bronze as compared with gun-metal. Messrs. Maudslay cast some manganese bronze into bars 1 inch square, and some gun-metal bars of t quality they could make of the same size. Both laid on supports 12 inches apart, and while the manga-

nese-bronze bars took a weight of 52 cwt. applied transversely in the middle of the bar, the gun-metal bars would only bear half that weight. There was not the slightest difficulty in making sound castings with manganese bronze by the proper means, but some persons would not take the necessary trouble. They used various qualities of ferro-manganese, according to the quality of metal they wished to produce; and in the ferro-manganese used, not in the bronze made, the proportion of metallic manganese varied from 5 to 40 per cent.; but only about 2 to 4 per cent. of this ferro-manganese was mixed with the copper. This was about the same proportion as was put into steel. A small proportion of the manganese was used in deoxidising the copper and a very small proportion remained in the bronze; but this was in some cases as much as 0·3 per cent. It was found that up to a certain point an increase of the proportion of manganese increased the toughness of the metal. With regard to combining the metals in their atomic proportions, that was a point at which he had always aimed. He had no doubt that if the metal from which the tin separated out, of which mention had been made, had been examined, it would have been found that the copper and tin had combined in their atomic proportions, and that the copper refused to receive any more tin, until it was added in another multiple of its atomic proportion.

Mr. YOUNG said he had never found any difficulty in casting a straight bar in almost any metal; but if Mr. Parsons would tell them that he would undertake a pair of double barrels jacketed with their ports and valve-seatings all cast together, as was now the practice, and guarantee to make them sound, he should be inclined to have some faith in the bronze. He had found that even the Phosphor Bronze Company could not guarantee sound castings of plain ordinary bearings. He had seen as many as eight or ten rejected one after another as they had passed from the lathe-man.

Mr. NURSEY, in reply, called Professor Huntington's attention to the fact that in the paper he had defined bronze pure and simple as consisting of copper and tin, but which, however, was modified by the ancients as well as by the moderns by the addition of other metals. Mr. Schönheyder had referred to the question of the mixture of the component parts of modern bronzes in their proper chemical proportions. That was a question which, to his (Mr. Nursey's) mind, was still open to careful, impartial, and independent investigation. Until that had been effected there would be, probably, a great deal of confusion amongst those who attempted to make varieties of bronzes outside those

persons who had devoted careful study to the subject, and who knew perfectly well what the chemical proportions were. That was one of the contentions of his paper.

The CHAIRMAN said he had no doubt that many of the difficulties which had been mentioned in connection with the preparation of the modern bronzes were also encountered in casting ordinary brass. Two metals of different melting temperatures had to be dealt with, and unless that was done by someone having experience in combining them, the result was frequently a failure. They were very much indebted to Mr. Nursey for the paper which he had read, and for the great trouble he had taken in preparing the diagrams. No doubt his work would prove a very interesting addition to the Transactions of the Society.

November 3rd, 1884.

PERRY F. NURSEY, VICE-PRESIDENT, IN THE CHAIR.

COOPER'S COAL-LIMING PROCESS.

BY PROFESSOR J. ALFRED WANKLYN.

IN King's treatise on coal-gas, numerous analyses of coal are given showing the percentage of sulphur in different kinds of coal, and from which the author quotes the following :—

	Percentage of Sulphur in Coal.
Derbyshire coals	0·91
" "	1·14
Gloucestershire coals	0·85
" "	2·67
Lancashire coals	0·80
" "	2·43
Scotch coals	0·32
" "	1·53
Welsh coals	0·70
" "	3·95
Newcastle coals, average of eighteen samples from different mines	1·24
Old Pelton	0·75
Pelaw	0·85
Washington	0·73
New Pelton	0·62
Leverson	0·69
Dean's Primrose	0·90
Londonderry	1·64
"	1·30
Gosforth	1·10
West Hartley	1·20
Hastings Hartley	1·50

When coal is distilled in the ordinary manner in the process of gas-making, part of the sulphur remains behind in the coke, and part of it goes into the gas in the form of sulphuretted hydrogen, sulphuret of carbon, and other volatile compounds. Hence the small percentages of sulphur shown in the tabular statement just given are a source of great trouble to the gas manufacturer. If coal were devoid of sulphur, the gas made from it would not require to be passed through purifiers, and after leaving the scrubber might go directly into the holder. But since coal does contain some 1 per cent. of sulphur, a portion of which enters into the gas, the gas manufacturer

has hitherto been compelled to have recourse to a process of purification by means of purifiers, which is very costly, and creates a great nuisance in the neighbourhood of the gasworks. The process of purification by means of purifiers is so familiar that the author need not describe it. As is well known, one of its incidents is the periodical discharge into the open air of large volumes of foul lime or foul oxide of iron; and, as is equally well known, it is the effluvium thrown off into the atmosphere by the foul lime and foul oxide which constitutes the chief nuisance arising from the manufacture of gas.

The cost of the process of purification by means of purifiers may be arrived at by reference to the published accounts of gas companies, and to the evidences given by eminent gas engineers before Parliamentary committees. The following summary will be found to be in accordance with the facts which have come to light. Gas companies (for instance, the gas companies of London) which manufacture very pure gas, spend 8·31*d.* per ton of coal carbonised. Gas companies which do not manufacture very pure gas, that is to say companies which do not trouble themselves to reduce the sulphur to 15 grains per 100 cubic feet, usually spend about the half of that sum on the purification of gas. The author has also to mention that these figures relate solely to the cost of labour and material, and are exclusive of interest on the capital sunk in the erection of the purifiers and the purifying-house, and exclusive of ground rents. On this subject the evidence of Mr. George Livesey, of the South Metropolitan Gas Company, is very instructive. The evidence was given on June 17th, 1880, before a Parliamentary committee, and is quoted by Mr. Spice in his book on the purification of coal-gas, page 29. Mr. Geo. Livesey said:—"All I can say on that point is this: If the town wishes to have gas at a maximum of 20 grains of sulphur impurity they must pay for it. It involves double the extent of purifiers that would otherwise be required if there was no restriction, and it involves about double the quantity of materials and the labour of purifying." Replying to counsel's remark, "You have not considered in this case the question of the standard price," Mr. Livesey said, "I have considered it to this extent, that a certain standard is sufficient without restriction. They would want 2*d.* more per 1000 feet with these restrictions." Replying to counsel's observation, "You have differed from some of the witnesses who have been called, who say 1*d.* per 1000 feet would be enough," Mr. Livesey continued: "I take it that 1*d.* per 1000 feet is interest on the capital expended on the additional plant, and another 1*d.* for extra labour, and there is the nuisance besides, which the

public would have to submit to." Inasmuch as a ton of coal yields about 10,000 cubic feet of gas, Mr. Livesey's evidence amounts to this—that the cost of the extra purification requisite to lower the sulphur to 15 grains per 100 cubic feet of gas is about 20*d.* per ton of coal carbonised, 10*d.* being for labour and material, and 10*d.* for interest on capital sunk in plant.

This, then, was the condition of the gas industry in this respect up to the date of Cooper's coal-liming process, which the author will presently describe. The coal used in gasworks contains about 1 per cent. of sulphur. When gas is made, part of this sulphur enters into the gas. To rid the gas of this sulphur, and thereby to render the gas fit for the use of civilised society, costs 8*d.* or 10*d.* in labour and material per ton of coal carbonised, and 8*d.* or 10*d.* in interest on plant, and entails upon the gasworks the creation of one of the worst nuisances in the whole range of manufacturing industry.

In this condition of affairs Cooper's coal-liming process supplies a remedy by manufacturing gas up to the London standard of purity, and saving 90 per cent. of the cost of purification, and abstaining from the creation of the nuisance. If we could find a supply of non-sulphurous coal, or if we could extract the sulphur before carbonising the coal, the difficulty would be got over. But there is no probability of our accomplishing either of these tasks, and Cooper's process sets to work in another way. It neutralises the sulphur in the coal by means of a slight excess of lime. To 1 ton of coal ½-cwt. of quicklime is added. The lime is slaked with about its own weight of water and mixed intimately with the coal. At the Tunbridge Wells Gasworks, where the process has been in operation for about twelve months, the lime and coal in the proportions stated are fed into an incorporating mill, in which they are blended by being passed between a pair of toothed rollers. The limed coal falls into a receiver, from whence it is lifted up by elevators to fixed hoppers in the retort-house, where it is stored for use and is supplied to the charging apparatus as required for the retorts. It is a well-known chemical fact that at the temperatures, and under the conditions realised in the interior of the gas-retort, sulphur has a greater tendency to unite with calcium than to unite with hydrogen, or with carbon, or with oxygen, and if there were absolutely perfect mixture of the lime with the coal, there would be absolutely no escape of any sulphur into the gas. In practice the mixture is only approximate, and accordingly in practice the purity of the gas is approximate. But the approximation is good enough to ensure the most important

results. During the two years which have elapsed since Cooper's process was introduced to public notice, ample opportunities have been afforded of demonstrating the efficiency of the process in yielding gas only slightly charged with sulphur. In a paper which the author read before the Society of Arts in the early part of this year he gave comparative analyses of gas produced from limed and from unlimed coal. The coal employed in the experiments was of the most varied kind; the scale was larger, the gas being taken from retort-houses carbonising about 1000 tons of coal a week. The analyses were very numerous, amounting to several hundreds, and—as the following specimens show—the results were quite unmistakable:—

January 30, 1883.	Grains of Sulphur per 100 cubic feet of Gas.	
	Limed Coal.	Unlimed Coal.
I.	14·4	26·3
II.	17·1	26·3
III.	15·9	—

The figures express the results arrived at by the Harcourt method of testing.

The effects of the lime on the sulphur compound, even when the mixture of the lime with the coal is imperfect, are so striking that it is hardly possible for any experimenter to overlook them when his attention has been directed to the subject; and even Mr. Hack, whose report to the Birmingham Corporation was conspicuously adverse to Cooper's process, did not fail to show the diminution of the sulphur compounds which that process brings about.

At the Tunbridge Wells Gasworks, where the Cooper process, as already stated, has been worked for an entire year, the results are most satisfactory. At these works the coal is a very inferior variety of New Pelton, consisting for the most part of slack, and containing, according to the author's analysis, 1·7 to 1·3 per cent. of sulphur. Under ordinary circumstances, such coal might be expected to yield a gas which—unless purified by the lime-purifier—would contain from 25 to 50 grains of sulphur compound per 100 cubic feet of gas. During the year in which Cooper's process has been worked at Tunbridge Wells, and during which there has been no lime purifier at the gasworks, a mean of less than 13 grains of sulphur per 100 cubic feet of gas has been maintained. The author ought to add that this result has been arrived at w[illegible]everting to any specially intimate mixture beyond the

incorporating mill already referred to. The West charging machine is used at Tunbridge Wells, but none of the many obvious devices have been resorted to in order to increase the mixing power of the machine.

Viewing the question from a chemical point of view, the intrinsic superiority of coal-liming over the lime-purifier as a means of depriving gas of sulphur is obvious. If it were desired (as in time to come it may be) to manufacture gas with the sulphur reduced to 1 grain per 100 cubic feet, a chemist might hope to accomplish the task by a persevering endeavour to comply strictly with the directions of the Cooper process. By a suitable modification of the generating mass it is by no means an impossible task to generate a gas originally free from sulphuret of carbon. But to absorb the last trace of sulphuret of carbon contained in gas is a very much more difficult undertaking. The inferiority of the lime-purifier to coal-liming is aptly shown by the rise in sulphur compounds which takes place in winter. In pity for the necessities of the London companies, which have hitherto had to rely upon so troublesome an implement as the lime-purifier, the gas referees permit the gas in winter to contain 22 grains of sulphur for 100 cubic feet. If coal-liming were resorted to instead of the lime-purifiers, the London companies would require no such indulgence.

The removal of sulphuretted hydrogen from a gas which contains it is a very much easier task than the removal of sulphuret of carbon. Probably no impurity is easier to deal with than sulphuretted hydrogen. Gas—which, when it issues from the retort, is loaded with sulphuretted hydrogen—may be rendered absolutely free from that objectionable compound by the action either of the lime-purifier or of the oxide of iron purifier. But, as hitherto practised in gasworks, this absorption of sulphuretted hydrogen has always involved the creation of nuisance and the expenditure of a considerable sum of money. An indirect but very important result of coal-liming is the accomplishment of the removal of sulphuretted hydrogen without the creation of any nuisance and with diminution of the expenditure.

In order to explain how this comes about, it will be requisite to direct attention to the manner in which the oxide of iron purifier acts upon the sulphuretted hydrogen contained in coal-gas. There are two methods by which this purifier acts. One of these methods is action as an oxidiser; the other method is action as a carrier of oxygen. Oxide of iron acting as an oxidiser gives up oxygen out of its own substance, and in that way produces water and sulphur when sulphuretted hydrogen

passes through it. Oxide of iron acting as a carrier of oxygen acts by causing the oxygen contained in traces of air to unite with sulphuretted hydrogen. Both kinds of action have been known for many years, and both kinds of action have been employed in gasworks for many years. Between these two methods of action there is a very vital practical difference. Action as an oxidiser is productive of nuisance, and is costly. Action as a carrier is devoid of nuisance and is economical.

Up to the present time, in most gasworks, very nearly the entire action of the oxide of iron has been action as an oxidiser. In a few gasworks, here and there, about half of the action may have been of the carrier kind. But at Tunbridge Wells—and as yet only at Tunbridge Wells—the entire action of the oxide of iron has been confined to the carrier kind. And this great achievement has become possible through the adoption of the Cooper process, which so far limits the proportion of sulphuretted hydrogen in the crude gas that traces of air become amply sufficient for the destruction of the whole of the sulphuretted hydrogen contained in the gas. In conclusion, the author would observe that the Cooper process is singularly free from drawbacks of any kind. The lime which is mixed with the coal returns more than its money value in the shape of the increased yield of ammonia. The coke is increased in quantity, and improved in quality. There is neither diminution of the volume of the gas, nor deterioration of its quality. There is not even a falling off in the yield of gas per mouthpiece when the process is properly worked. And there is no appreciable destruction of the furnaces which can properly be laid to the charge of the coal-liming process.

DISCUSSION.

Mr. CHARLES GANDON said he had listened to Professor Wanklyn's paper with considerable interest, because he had heard a good deal about limed coal of late, and it had appeared to him that undue claims had been put forward with regard to its benefits. He believed that at one time Professor Wanklyn accused the gas engineers of England of unnecessarily poisoning the atmosphere by the way in which they purified the gas, but he felt confident that every gas engineer would hail with great pleasure any means by which the purification could be performed in a more simple way than that which had been hitherto practised. He had made a few experiments with the coal-liming process to ascertain whether he could do anything with it. It would occur to every one that if lime was mixed with the coal a certain portion of the sulphur contained in the coal

would be arrested in the retorts, and certainly to that extent there must be an advantage in the mixing. Another claim was that more ammonia was produced, which was a very important item. From his own experience he could say very little about the increase, but it seemed that many who had tried the process had obtained an increase of ammonia, in some cases a considerable amount, and in others very little. What had concerned him most was to know whether the compound of sulphur and carbon, the great incubus to all gas-makers, could be sufficiently reduced to enable the process to be substituted for the expensive and imperfect plan now in vogue, namely their absorption by means of lime in the purifiers. His experiments were carried out on a small scale, and though they tended to show that the compounds of sulphur and carbon were reduced, yet they were not reduced sufficiently to enable him to use the process as a means of complying with the stipulations of the Act of Parliament under which he worked. Perhaps if his trials had been made upon a larger scale different results might have been obtained. But he had seen working results made in other places confirming the opinion he had formed, which was, that the compounds of sulphur and carbon could not be brought down to his margin by the process, namely to a maximum of 20 grains per 100 cubic feet of gas. There was no doubt that, when the coal was limed, less duty was thrown upon the ordinary purification of the gas as now carried out, but it became a matter of calculation whether the results obtained paid for the means adopted in obtaining them. An intimate mixture of the coal and lime appeared to be necessary, and Professor Wanklyn had drawn attention to that point. In his trials he had no means of effecting such a mixture, but he believed it was to a great extent obtained at Tunbridge Wells by the adoption of West's charging apparatus, with which it was necessary to reduce the coal to a fine powder. He understood Professor Wanklyn, in giving some comparative analyses between the sulphur contained in limed and unlimed coal, to state that the results were obtained by what was known as the Harcourt test. He (Mr. Gandon) had no faith whatever in that test for obtaining absolute indications of sulphur. He had found it entirely unreliable some years ago. At times the results it gave agreed with those obtained by the ordinary tests for ascertaining the amount of sulphur left in the gas, and at other times they were completely at variance. He should like to know whether any experiments had been made with what might be called the referee's test, or any other ordinary test for ascertaining the amount of sulphur in gas. He understood that from the experiments made at Tunbridge Wells, it was claimed that an oxide of iron purifier would run for a very long time, some

twelve or thirteen months, without requiring to be changed, and that that was due to the Cooper liming process. He thought there was some little misunderstanding, that a certain amount of air was, he believed, passed in with the gas; and they all knew that, if 1 or 1½ per cent. of air was passed in, it had the effect of revivifying the oxide, and therefore if sufficient air was passed, the purifier would last for an almost indefinite period without requiring to be turned out. In fact, it only required to be turned out when it got so caked together that the gas would not pass through. He thought that might to a certain extent account for the long duration of the purifiers at Tunbridge Wells. It also occurred to him, although he had had no means of proving it, that the admission of air might have had something to do with the increase of ammonia. Air was composed of oxygen and nitrogen, and if the oxygen was absorbed by the sulphuretted hydrogen, a certain amount of nitrogen would be set free which might possibly combine with the other elements in the gas to form ammonia. He merely put this forward as a suggestion. He felt certain if gas engineers could satisfy themselves that by the mixture of lime with coal the process of purification could be relieved of the many onerous and difficult operations now connected with it, they would adopt the process with the greatest satisfaction. One thing which rather cooled his ardour with regard to it was, that he found the admixture of the lime with the coal formed a flux which had a very serious influence upon the durability of the furnaces, but perhaps that would not be the case when the coal and the lime were more intimately mixed.

Mr. ARTHUR MEAD said that he had the privilege of being present at Tunbridge Wells a short time since when the purifier of which so much had been said was opened. He was informed as to the quantity of oxide put into the purifier, and he was much astonished at its increased bulk when it was opened. It had occurred to him, and doubtless to many others, that the result might have been due to the mixing of air with the gas, and he then questioned Professor Wanklyn on the subject, and suggested that the length of time which the purifier had lasted was due mainly to the admission of air, as Mr. Gandon had just suggested. Professor Wanklyn's reply to him was that the quantity of sulphuretted hydrogen in the gas had been so much reduced by the mixing of lime with the coal in the retort that they were enabled, by using a very small proportion of air, to neutralize the effect of the sulphuretted hydrogen in the purifier so that it lasted a very long time. If 2 or 3 per cent. of air were mixed with the gas, as might be required with the ordinary process of

manufacture, the illuminating power would be so much reduced that the gas would be practically useless. Mr. Gandon had asked a question which he (Mr. Mead) should have himself asked with reference to Harcourt's test. In Mr. Harcourt's instructions for using his test, after they had ascertained the quantity of sulphur contained in 100 feet of gas, they were told to add 7 or 8 grains more for other compounds of sulphur. He should like to know whether those other compounds were included in the quantities which Professor Wanklyn had put before the meeting.

Professor WANKLYN said that such corrections were not made.

Mr. MEAD added that he had been very much interested in the process. Referring to the remark made by Professor Wanklyn, viz. that by the adoption of the Cooper Coal-liming Process the provincial companies would be enabled, without incurring additional expense, to raise their standard of purity &c., to that of the London companies, he (Mr. Mead) being connected with some provincial companies, was of opinion that the provincial gas companies would not take second place to the London companies in that respect.

Dr. POLE said that the Metropolitan gas referees, of whom he was one, were much interested in all matters relating to the sulphur in gas, and he could answer for his colleagues that the process which had been explained would have their attention. He regretted he was unable to add anything to the discussion, as he had at present no knowledge of the process, except from what he had heard and read.

Mr. WILLIAM FOX said that he had seen the process in use at several gasworks, and had paid particular attention to the subject of fluxing. It was well known that sulphide of calcium was present as one of the constituents of the ash of limed coke, and that a flux would be readily formed of it, but not with the constituents of the brickwork. In order to have the flux formed it was necessary to have an intimate mixture of the material forming it, such a mixture was not obtained between the brickwork of the furnaces and the sulphide of calcium present in the coke, and, in preference, the sulphide of calcium simply fluxed with the constituents of the ashes of the coke. He thought any one who understood chemistry would see that an increase of ammonia must take place in Cooper's process. At the same time the probabilities were that there should be an increase in the amount of carbonic acid gas, but the evidence at present was that the illuminating power was not altered. It would therefore be interesting if some information could be given as to whether any richer illuminants were given off during the

distillation of the limed coal than during the distillation of ordinary coal.

Mr. SCHÖNHEYDER said it seemed to be most important that the coal and the lime should be mixed thoroughly, and Professor Wanklyn had stated that if they were so mixed the sulphur would be almost entirely eliminated from the gas. He believed that the lime was sprinkled over the coal in some way or other. It appeared to him that the only way in which an intimate mixture could be produced was by grinding both the coal and the lime at the same time, and allowing them to issue in streams and mix together in the proper proportions. For use in Mr. Crampton's coal-dust furnace the grinding of the coal into dust had been accomplished at a cost of a very few pence per ton.

The CHAIRMAN said he had availed himself of an opportunity to visit the Tunbridge Wells Gasworks about two months ago. They were by no means small works, but were capable of carbonising 10,550 tons of coal per annum, which was equal to a yield of 110 million cubic feet of gas. The coal used was of an inferior character. It was New Pelton coal, and he noticed there was a great deal of slack in it. The coal and lime were mixed in the proportions stated by Professor Wanklyn, which were half a cwt. of lime to one ton of coal. They were first roughly mixed by hand and fed into a pulverising machine consisting of a pair of toothed rollers, which ground the materials rough-fine. From the mill they were elevated to receivers placed inside the retort-house. It was then drawn into West's charging machines as required for charging the retorts. The result of the liming procces was to make a great difference in the quantity of sulphur which was present in the gas. The process hinged upon the fact that the lime was used at the commencement of the process instead of at its close. He had had the opportunity of examining the coke, and so far as he could judge it had no trace of lime in it. He was not aware that any damage had been done to the furnace-bars, and he believed he should have heard of it if it had existed. There was no doubt that when the coke thus produced was burned it did not evolve sulphur. He had had an opportunity of testing that fact by a fire in the office at the Works. He examined the products of combustion, but could find no trace of sulphur in them. He understood that it was thrown down with the ash. As to the question of the gain in ammonia, he saw the process of manufacture carried out at Tunbridge Wells. The company made their own sulphate of ammonia and effected an absolute gain, which, he believed, was shown by their accounts to be no less than 30 per cent. above the ordinary process. Professor

Wanklyn had observed that if the coal and lime were more intimately blended by means of more refined machinery a still better result might be obtained. That method, however, would be attended with some extra expense which might vitiate the profit. At the same time it seemed to him that it could not detract from the value of the invention, which, as far as he had been able to learn, had perfectly succeeded in ridding gasworks of one of the greatest nuisances which they had to contend with, namely lime-purifiers.

Mr. R. P. SPICE said he had hoped he should have heard much more advanced against the process than he had heard that evening. He concluded that there was nothing more to be said against it than had been said. There was, however, a great deal to be said upon the subject. The process was introduced to his notice by the patentee, Mr. W. J. Cooper, and he promised to look into it. The difficulty which presented itself was the mixing of coal with lime in a retort-house. He felt that such a method would be against the grain of his brethren in the gas-manufacturing world. He did not then quite see his way to making such a mixture, as it was unorthodox, and he felt that it would be unpalatable to gas-makers. However, after reading the papers which Mr. Cooper left with him, he could not help seeing that there was something in the process, and in discharge of his duty as Consulting Engineer of the Tunbridge Wells Gas Company he determined to try the process on a practical scale at the Tunbridge Wells works, provided the directors would sanction it. He obtained the consent of the directors on condition that he should not give up the control of the works to Mr. Cooper, or to anybody else, and that he should be at liberty to put an end to the experiment when he chose to do so. He was then just about going to Madeira, and he left Mr. Cooper and Professor Wanklyn to carry out their experiments at Tunbridge Wells in conjunction with his representative, Mr. Dougall, the manager of the works. After an absence of two months he returned to the works, and examined what had been done, and though he was certainly agreeably surprised, he could not say that he was entirely and conclusively satisfied. He wanted to ascertain what the sulphur compounds were at the time the experiments were commenced, but he found that no observations had been made on that subject for several months before the experiment with the liming process commenced. In consequence of that, the old process was resumed, and observations were taken as to sulphur compounds, and these were found to jump up immediately to 26 grains. The second dose which he gave the purifier, by sending forward all the products of the distillation, instead

of arresting the sulphuretted hydrogen in the retorts, so gorged the contents of the oxide purifiers that he was not able to get back to the very satisfactory state of things which existed before the old process was resumed. A correspondence had taken place between himself and one of the Gas Referees, Mr. Vernon Harcourt, and as the result of chemical knowledge of the highest class, that gentleman had computed that five-sixths of the sulphur contained in the crude gas was arrested in the retort by means of the liming process, and therefore that only one-sixth of the impurities were left for the purifier to deal with, and it was a very singular fact that that scientific deduction of Mr. Vernon Harcourt's corresponded with his (Mr. Spice's) practical experience at Tunbridge Wells. At those works there were six purifiers 20 feet square; equal to a make of 200 million cubic feet per annum. Five of the six had been used for purifying the gas by the ordinary method, so that the quantity might be within the requirements of the London Gas Referees, although the Company was under no obligation to maintain that high standard of purity. In establishing and carrying on the Tunbridge Wells works, he determined the work should be done in the best possible way, and to supply gas as pure as it could be manufactured. The gas did not contain more than ten or twelve grains of sulphur compounds in the 100 feet. After the liming process was introduced they used only one purifier out of the six, instead of using five of them as formerly. That showed that their practical experience corresponded with remarkable nearness to the scientific deduction of Mr. Vernon Harcourt, for, according to the experience which had been obtained at the Tunbridge Wells works, the liming process got rid of four-fifths of the sulphur impurities, while according to Mr. Harcourt's theoretical conclusion, it would get rid of five-sixths. That threw a flood of light upon the remark which Mr. Gandon had made with regard to the vitality of the purifiers continuing so long. He wished to assure Mr. Gandon that the difference was not due to the 1 per cent. of air which he seemed to think worked such wonders. At Tunbridge Wells, they worked without any air at all for the first three months, but previously they were only able to work for ten days in winter without air on the old plan; that was to say, they formerly had to change the oxide of iron purifier once in ten days, whereas they were now able to use it for ninety days in mid-winter, and perhaps they might have used it without air for a much longer period. But they found by a mere accident that, in consequence of some air getting into the apparatus, double the quantity of sulphuretted hydrogen was arrested, and hence less went on to the second

purifier. Professor Wanklyn at once said "This can only be accounted for by some air getting in." Mr. Dougall and Professor Wanklyn then consulted and agreed to measure a little air into the purifier. They first tried ½ per cent., and then they tried 1 per cent., and the effect of the latter quantity was to do what he (Mr. Spice) had just described, for about 98 per cent. of the sulphur which came to the inlet was arrested within the purifier, and from that time to the present, whatever quantity of gas has been manufactured, 1 per cent. of air had been passed by measure through the inlet of the first purifier, and that had enabled them to go on doing what they had done, which was, to work for eleven months through one purifier, continuously, without changing it. He would say to his gas friends, "Try 1 per cent. on the old system, and see where it will land you, and observe whether 1 per cent. of common air will enable you to meet the requirements of the Referees." One per cent. of air would cause oxidation to a certain extent, but for air to do any good in oxidising *in situ*, the 1 per cent. must be multiplied by three or four, and that would bring the illuminating power down so low that the use of such a large quantity of air would have to be abandoned. Common air would not make the gas which the consumers wanted. He would say in the face of the gas world, that without the liming process for arresting five-sixths of the impurities, as was done in the retort, no amount of common air would put them right or keep them going. If they used air enough to re-oxidise the oxide of iron within the purifier while the gas was passing through it, they would bring down the illuminating power. Mr. H. P. Stephenson, the Chairman of the Crystal Palace District Gas Company, before a Parliamentary committee in 1877, said, "No process has ever been brought to our notice by which we could discharge the sulphur from the gas without creating a nuisance. If it had been, we should have adopted it, unless it was at an enormous expense." Those were his words in 1877. He (Mr. Spice) now found from a recent report of this Company that its directors are waiting for universal approbation, before adopting a process involving no expense, but affording considerable additional profit, and pure gas, without committing a nuisance, that is by abolishing the lime-purifier, and not having to open the oxide-purifier. In eleven months, at Tunbridge Wells, they had purified 101,627,000 feet of gas as efficiently as London gas was purified, at a cost for revivification of only 3*l*. He had asked the manager of the works to inform him what was the cost of emptying the purifier, which had been opened in the presence of a number of scientific men, and of revivifying the oxide and recharging the vessel. The answer was that the

entire operation cost 3*l*. Now, on the old plan, purification would cost a penny per 1000 feet, and this would be 423*l*. 8*s*. 11*d*. The interest on plant required in excess of that which would be ample for the coal-liming process would amount to another penny per thousand, amounting together to 846*l*. 17*s*. 10*d*. He gave those figures on the authority of the evidence given by Mr. George Livesey, of the South Metropolitan Gas Company, in his examination before the Parliamentary committee on the Maidstone Gas Bill. The cost of revivifying incurred at Tunbridge Wells was only 3*l*. The cost of the lime used in the retorts not recovered in the sale of coke was 37*l*. 10*s*., making together 40*l*. 10*s*. That was all it would cost to do the purifying at the Tunbridge Wells works by the aid of Cooper's Coal-liming process. That sum deducted from the 846*l*. 17*s*. 10*d*. showed a saving of 806*l*. 7*s*. 10*d*. upon the 101,627,000 cubic feet of gas manufactured. That was a saving which could be effected upon that quantity of gas, and this if applied to the quantity of gas made by the Metropolitan companies would amount to about 166,000*l*. Gas purified by oxide of iron only, as it too commonly was, contained from about 30 to 40 or more grains of sulphur in 100 feet. According to the report of the official examiner for the local authority at Tunbridge Wells, for the week ending the 30th of October (four days previously to the present meeting), the illuminating power of the gas was equal to 14·47 standard sperm candles. The sulphur per 100 cubic feet amounted to 11·23 grains, and the ammonia was *nil*. So far those figures related to the question of purification, and he (Mr. Spice) had shown a saving of 806*l*. 7*s*. 10*d*. in that respect. He would refer, in conclusion, to the profit from sulphate of ammonia, and that, by reason of 33 per cent. more being obtained than by the old method of carbonising, was the same at the present low price as at the prices which were ruling in 1882. Regret had been expressed by gas companies, and by corporations which made their own gas, on account of their profits having been seriously reduced by the diminution of the price of sulphate of ammonia, which was now worth only about two-thirds of its value in 1882. But, as a consequence of one-third more sulphate being produced by the coal-liming process, the former state of financial prosperity in that respect would be restored to every gas company that would adopt the process. He was sorry to say that he found great prejudice against the process, and it had been said that he was riding a hobby in this matter, but he would unhesitatingly assert that if gas-makers would mix 2½ per cent. of lime with the coal before putting it into the retort, the lime having been slaked with its own weight of water, they would find out that

he had spoken nothing but the truth as to the value of the process. He hoped that he should have opportunities of seeing very much more done in the way of the application of the system, for he knew that it was a right one, a profitable one, and a good one, and he knew that it was one which before long would prevail, and be hailed as a benefit of no small magnitude both as regarded economical and sanitary considerations.

Professor WANKLYN, in reply, said, that a question had been asked about the method by which the Vauxhall figures were obtained. They were obtained by Harcourt's process, and the figures which he had placed before the meeting were the uncorrected figures, that was to say, the figures as directly read off. There were many hundreds of them. The Harcourt process was a very convenient one, and it could be applied in cases where the other process could not be applied. The Harcourt process was resorted to in this instance because there were small quantities of gas. He was quite aware of the defects of the process. On other occasions they had tried the Referees' process, and hundreds of experiments had been made by it. For his own part, he was not even satisfied with the Referees' process, and he believed that it failed occasionally. It took the sulphur compounds, and converted them into sulphurous acid, and then the experimenter trusted to chance to convert the sulphurous acid into sulphuric acid. It generally happened that traces of oxide of nitrogen were formed during the combustion of ordinary flames. If it were not for that, the Referees' process would always fail lamentably. He believed that it always failed to some extent, and sometimes totally. In consequence of that he had been led to devise a process which could not by any possibility fail. He used an oxidising material. Instead of using carbonate of ammonia he used iodine, and so he could not fail to oxidise all the sulphurous acid. He was pleased to find that the late Mr. Keats had resorted to such a process. It was a very obvious thing for a chemist to apply an oxidising agent in a case of this kind, and the extraordinary thing was how the Referees could have gone on for years without recommending an oxidising agent. At Tunbridge Wells, in addition to the official testings, there were testings by the iodine process. It was the severest and most trustworthy method of determining the sulphur compounds. Ever since the Cooper process came out, the patentee and those associated with him had been under certain temptations to ascribe to the process things that it did not do. One of the earliest things they noted was that in ordinary gas-making a great deal of the ammonia that was present was lost. The reason why such irregular results had been obtained was the loss of ammonia, and the defective way

in which the liquor was dealt with. Mr. Cooper was under some temptation to take the credit not only of extra ammonia produced by the lime, but of a further increase of ammonia due to better collection. He (Mr. Cooper) had, however, from the beginning, steadily warned gas-makers that part of the increase of the ammonia which would ultimately be got would be due to better working. In ordinary gas manufacture, 5 or 6 lb. of ammonia were obtained per ton of coal. He (the speaker) believed that, by thorough liming and excellent working, from 12 to 15 lb. of ammonia per ton would be obtained, but that had never been obtained as yet. There was at present a gain of from 30 to 40 per cent., which he believed was due essentially to the Cooper process, but there was room for better preservation of the ammonia. He had made inquiries as to what had been done with regard to admitting air, and he had found that for the last twenty years, at intervals, various gas manufacturers had admitted air into gas, but most of those that had done so had abandoned the practice. Purification in closed vessels was not the result of the admission of air into ordinary crude coal-gas; but if they had gas from limed coal, and they admitted a proper quantity of air, then there would be purification in closed vessels, and they might not only make one purifier last for a number of years, and go on having sulphur accumulate in it, but they might actually dispense with the use of any catch purifier. It was perfectly true, as Mr. Gandon understood, that if a little air was admitted the purifier might be made to last for years. But if that was done with the ordinary gas they would use up the purifiers that were in front. What they had done at Tunbridge Wells was to make the first purifier last without using up any catch purifier whatever. The contents of the purifier that were thrown out on the 16th of last month had been revivified. One-half (viz. about 15 tons) had been put back into the purifier, in two thin layers, the lower one of 6 inches, and the upper one of 12 inches. The proper quantity of air was admitted, and the gas as it escaped was perfectly free from sulphuretted hydrogen, and the purifier would go on for two years at least, The use of the catch purifier was simply a measure of precaution; and the difference between this process and the working with ordinary gas, was that they might make purifier number one go on lasting, without entailing the exhaustion of purifiers placed as catch purifiers. When the single purifier accomplished all the work, and went on, lasting for two years, it was not a purifier in the ordinary sense of the word, but it was a dry scrubber. At Tunbridge Wells the purifier had given place to the dry scrubber.

The CHAIRMAN, in closing the discussion, said that only one speaker had said anything against the process, and the objections which that gentleman (Mr Gandon) had made were of a limited and qualified nature. Mr. Gandon said he had tried the process and had not succeeded, but he admitted that he had only tried it experimentally. But even so far Mr. Gandon's experience was a testimonial in favour of the process, for he found a sensible reduction in his sulphur compounds. Had he introduced it at his works on the same scale on which it had been carried out at Tunbridge Wells and in the same thorough manner, he (the Chairman) did not know why Mr. Gandon should not have succeeded in exactly the same manner as they had at Tunbridge Wells. No doubt he would have done so, unless there were peculiar and antagonistic conditions at Mr. Gandon's works. On the other hand, the meeting had heard Mr. Spice's forcible remarks upon the merits of the process, and his assertions and statements had not been in any way questioned, much less contradicted; and the meeting might take it for granted that the results were as laid down by Mr. Spice from his experience of a year's working at Tunbridge Wells. In fact the Cooper Coal-liming Process, as carried out there, constituted a marked step in advance upon the usual practice of gas-making. It was, moreover, one which appeared to be of the greatest value to gas companies, especially those within the Metropolitan area. It occurred to him (the Chairman) that the position of the Cooper Coal-liming Process was in many respects analogous to the position which was once occupied by the Thomas-Gilchrist process for eliminating phosphorus from steel. For several years attempts were made to bring forward that process. At a meeting of the Iron and Steel Institute held in Paris in 1878, the question was as fairly burked as ever any question was. There was doubt about the process and prejudice against it on the part of many of the leading ironmasters and steel-makers, although some few believed in it. But in 1879 a paper was read by Mr. Thomas, and the merits of the process were quickly recognised, and it soon received a considerable amount of support. It was first warmly taken up in Germany, where the manufacture of steel upon the Thomas-Gilchrist principle was speedily entered upon. Ultimately the process was tried in England. That was in 1879, and that year might be regarded as the starting-point in the application of the process. The progress soon became so rapid that in 1883 the total output of basic steel as it was termed, in contradistinction to that made by the acid process, was 634,373 tons. As he had observed, there seemed to be a very close analogy in this respect between the two processes.

From what he had seen at Tunbridge Wells, and from what he had heard that evening, he thought there was a future for the Cooper Coal-liming Process as great as there had been for the Thomas-Gilchrist process. He would thank Professor Wanklyn on behalf of the meeting for his paper. It had excited a great deal of interest. The process was new to many of the Members, but he trusted it would soon become well known to all.

December 1*st*, 1884.

ARTHUR RIGG, PRESIDENT, IN THE CHAIR.

THE BLOWPIPE-FLAME FURNACE.

BY A. C. ENGERT.

THE importance of the question of the defects of steam-boilers as regards corrosion, pitting, and incrustation, has been very clearly demonstrated during the year which is now nearly closed, by the attention which engineers and men of science have given to the subject, and by the papers which have been read before the various scientific societies with respect thereto. The proposed remedies for these defects are far too numerous to be stated by the author, but he proposes to glance at some of the chief of them as given in papers read before various professional societies.

The first paper for notice is one which was read on February 27th, 1884, before the Society of Arts, by Mr. Swinburn King, on "The Causes of Corrosion, Pitting, Incrustation, and Explosions of Steam Boilers." In this paper the author stated that the latter might be caused by the former. He gave some particulars respecting the committee appointed by the Admiralty, which sat from 1872 until 1880 to inquire into the causes of the decay of marine boilers, and which committee gave an elaborate report, but did not arrive at any satisfactory conclusion. Mr. William Weston, the chemist to the Admiralty at Portsmouth, a member of that committee, continued his researches, as some boilers had to be removed, owing to corrosion, after three or four years' service, at a cost of 50,000*l*. This gentleman, after trying zinc plates, finally adopted the plan of attaching a zinc ball to the top of the boilers of the Royal Navy, the ball being connected by a copper wire to the sides and bottom. The invention is that of Mr. Hannay, of Glasgow, who found that certain parts of the boiler were exceedingly hot, and other parts were kept very cool by the blast of cold air. This produced a galvanic action, the great heat at the top of the furnace or firebox causing this part of the metal to differ entirely from the other parts, and to become negative, whereas colder parts become the positive pole and waste away. In other words, pitting and corrosion set in.

To counteract this, a zinc ball was placed at the top in the boiler, and wires soldered to the side and bottom plates, and this reversed the action. The zinc ball becomes the positive pole, and wasting away and pitting cease as long as there is zinc and the connection holds good. This important preventive measure is now generally adopted, and this view accepted by most scientific men. But this extraordinary action is not the only result. Electricity is decomposing a small quantity of water in the boiler the hydrogen of which is evolved from the negative pole, or the iron of the boiler; and wherever there is any settlement or scale, it is forced up from the plates whenever there is sufficient hydrogen accumulated, so that the danger of burning the plates is entirely avoided.

The next paper, on boilers, was read on March 3rd, before this Society, by the author, in which he described a newly-designed boiler having two flat flues with vertical tubes and great heating surface, thus preventing priming, short slanting fire-bars, no ashpit, and having a feed-water heater, to extract air and settle all solids of carbonates, &c., so that almost pure boiling water is pumped into the boiler, which was shown by independent reports to evaporate as much as 11·3 lb., and by another test 11·85 lb. of water per pound of coal. The water was raised from 81° Fahr., and the steam formed was as dry as if superheated, on account of the high steam-space in the boiler. It had, moreover, only from 3 to 4 inches of water over the large flat flue, so that no convulsive force was required to penetrate a deep column of water for the steam formed over the plate to rise. The steam rises quite easily without forcing up water, which would cause priming. In this boiler the circulation is so great that no scale can be formed in the vertical tubes, only a little whitish mud being found on the top of the flat flue, and which is washed out by water. No unequal expansion exists, and as there is no ashpit the whole boiler is bricked in and produces no smoke. As no cold air can get into the furnaces, galvanic action cannot take place, as there is very little difference in temperature in this boiler, so that the plates are preserved and many dangers avoided. Since the author read that paper he has made a vertical boiler on the same principle, or rather two sections of a vertical boiler connected together by vertical tubes, and in the firebox of which the outside plate is bolted to the two sections, the firebox being lined inside with firebricks. This produces a rapid circulation of the water by reason of the vertical tubes and the large flat part of the top section of the boiler over the fire, which allows a large space for the steam. The author believes this is the

first vertical boiler to produce thoroughly dry steam, there being only 4 or 5 inches of water over the firebox. On the back of the firebox there is a water heater to drive out the air and to settle the solids at the bottom, the heated water being forced into the boiler by an injector.

On April 3rd, at the Institute of Naval Architects, Mr. James Howden read a paper on the combustion of fuel in furnaces by natural draught and by supply of air under pressure. Mr. Howden stated that the trials were not quite complete, but he observed that forty years ago in Cornwall an evaporation power was obtained of 12·89 lb. of water per lb. of coal from 212° Fahr., but that now not more than 6 lb. of water could be evaporated from a Cornish boiler on account of the forced draught. He tried to prove that with a natural draught great economy was produced as better combustion was the result. There was no surplus air to be warmed, and less heat was sent away to the chimney. He states that the fan-blower has not been successful, except in locomotive boilers used in torpedo-boats, but that the marine boiler has been worked more successfully by the air pressure in the stoke-hole. Still it has a tendency to injure the boiler, as a column of cold air supplied at the rate of from 8 to 10 cubic feet per second must be detrimental, and he observed that Mr. Butler had stated that after several hours' trial many tube-plates became leaky. He then described a marine boiler of his own in which the ashpit and every part of the boiler is well closed in so that no cold air can enter anywhere except by pipes from a fan into the enclosure, in which the air gets warm, and is admitted partly into the ashpit and partly above the firebars. In this way Mr. Howden claims to have gained great results, but Mr. Parker, who had seen Mr. Howden's boiler at work, doubted if he could reach at once the 50 per cent. economy which he claimed. Mr. Wright, Mr. Bryce Douglas, and Mr. Marshall all questioned the anticipated result.

Before leaving Mr. Howden's paper, the author would quote the following statement from *Engineering*, for October 24th, 1884:—"Forced draught for marine boilers.—Within the last few days there has been tested on board a steamer on the Clyde, and with unqualified success, the system of combustion in steam-boilers patented by Mr. James Howden, as above described. The statements which were made by Mr. Howden in his paper are, however, we are informed, fully corroborated by the result. The *New York City* is a vessel of 1754 tons gross, and was built at Stockton about five years ago. She has recently been re-boilered by Mr. Howden. Her original

boilers were double-ended, fitted with four furnaces, each 3 feet 5 inches diameter, and having an aggregate firegrate area of 75 square feet. Mr. Howden fitted the vessel with single-ended boilers, having only three furnaces, each 3 feet 4 inches diameter, and an aggregate firegrate area of 36 square feet. The results of the trial made on the Clyde, shortly stated, are as follows:—The forced draught easily maintained, and higher pressure of steam than that produced in the natural draught boilers; the engine ran on an average of three revolutions more per minute. The consumption of coal was 9 cwt. per hour against an average at sea of 12½ cwt. for the natural draught boiler."

On August 6th, at the meeting of the Institution of Mechanical Engineers held at Cardiff, a paper was read on the corrosion of marine boilers by Mr. J. Henry Hallett. The author observed that steel boilers were equally liable to corrosion as iron ones. Serious corrosion was often found concealed by a very slight scale, which, upon removal, showed the plate to be covered with a black substance, probably a black oxide of iron. The principal causes of corrosion are twofold, defective design and mismanagement. The most frequent fault was stated to be want of space for thorough examination of the interior; the tubes were often placed too far out in the wings, and the manholes were too small. Double-ended boilers, the writer observed, were especially liable to suffer from racking strain due to the difference of temperature between the upper and lower parts, and he thought frequent pumping up and blowing partly down when the engine was standing kept his boilers in good order. New boilers, he said, ought to be well washed out before being filled, and when boilers were put out of work they should be blown out to the bottom and kept quite dry. Corrosion in the upper part of the boiler, Mr. Hallett said, was principally caused by the introduction of grease from the engine. He said he had discarded the use of lubricants in the cylinders, and had tried various methods of preventing corrosion; and found Hannay's electrogen very effective. He thought circulation of the water was of the greatest importance. That paper gave rise to an important discussion, in which air in water was mentioned as being very destructive.

Many experiments with forced draughts have been made, and that system is now in practice, and many articles have been written both for and against it. One thing, however, is quite clear, and that is that forced draught causes a great waste of fuel, and is no doubt very destructive to some parts of the boiler so forced. A torpedo-boat, built by Messrs. Thorneycroft, was tried in January 1880, the following being the results:—

Air Pressure in Inches of Water.	Coal per Hour.	Temperature in Funnel.	Lb. of Water Evaporated per Lb. of Coal.
	lb.	Degrees Fahr.	
2	925	1073	7·06
3	1177	1192	6·60
4	1472	1260	6·33
6	1815	1444	5·97

Messrs. Yarrow & Co. conducted some trials with torpedo-boats in January last. Burning 15 cwt. of coal per hour, they found that the resistance to air-pressure was 1 inch in passing through the fuel, and $3\frac{3}{4}$ inches in passing through the tubes. The heat in the funnel and the great amount of smoke with its invisible gases alone would show the enormous waste going on in the furnace, besides which there is the wear and tear of the boiler and tubes. In locomotives a great waste is also going on. From 60 to 100 lb. of coals are burnt per square foot of firebars per hour, and complete combustion, especially in the marine boiler, is quite out of the question, as there is no time for the proper development of the flame and heat. Much less is there time for the heat to penetrate the metal for the formation of steam, and if means could be found to produce the required heat without the forced draught the gain would be very great.

The author having brought before the Members the substance of what has been written and said during the present year, and having given the different views expressed in connection with the subject of the defects of steam-boilers, and the difficulty in getting out of coal in the steam-boiler furnace the whole of the work contained in it, he will now explain the principle of his new furnace, which from its action he has named the blowpipe-flame furnace. In designing this furnace, economy in fuel and the preservation of the boiler have been his chief objects. Fig. 1 of the diagrams shows a front view of the boiler half in section and half in elevation, whilst Fig. 2 is a part longitudinal section. From the drawings it will be seen that the furnace has sloping firebars, on the back of which is built a raised fire-brick embankment some 3 feet 6 inches long; behind this is a dust pocket about 3 feet long, and then comes the ordinary bridge. In the front of the furnace is a shallow cast-iron box in which hangs a cast-iron plate reaching down to about 1 inch from the bottom of the box. The plate has at its lower end a few rows of holes or slots, and it may be raised altogether when firing is required. In front of the box are doors leaving also an inch opening at the bottom.

Fig. 2.

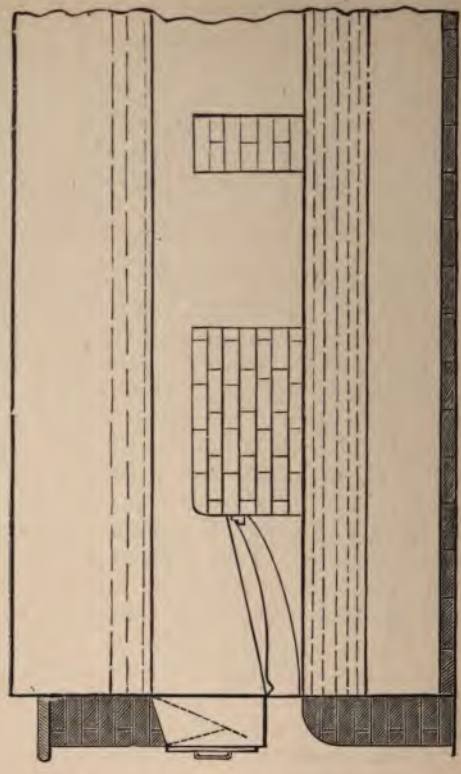
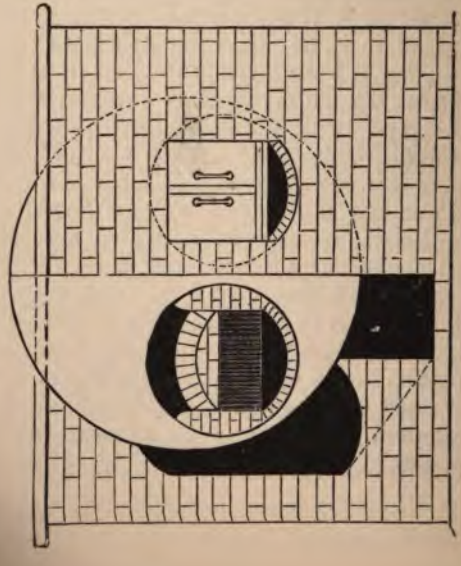


Fig. 1.



Combustion in nature may be favourable or unfavourable. In both cases there are degrees, and it is necessary therefore to find out the most favourable conditions for producing the most complete combustion, and to obtain the highest degree of heat with the smallest amount of waste in fuel. A fire lighted anywhere will produce a draught; but if a few stones are placed so as to form a back to the fire, then the draught will be stronger, and at certain points greater heat will be manifest. If a passage is then formed under the fire for a short distance, and a few more stones are placed in front and connected with those at the back, a foot or two high, a furnace is formed complete. The air can only enter at the bottom, and the heat evolved is confined to a certain space, which can then be led to wherever required without any diminution, except a little radiation, always supposing that no air is allowed to enter between the stones forming the furnace. Such entry would, of course, naturally diminish the heat, as part of the heat which had at first been formed must go over to the cold air. Besides, the various gases are condensed, and form smoke. This being a very important point, care ought always to be taken that the bottom or grate is well covered with fuel, so that no air can enter without coming in contact with the burning or incandescent mass, in order that every particle of oxygen may at once chemically combine with a certain volume of carbon and hydrogen gases to form heat; and as it is well known that nature is very economical, the engineer ought to imitate her, and see that no waste of air or fuel be allowed to go on in the furnace. The proportionate volumes of gases necessary for complete combustion are so well known that it is unnecessary to mention them here, but a comparison may be made with the ordinary furnace in use. In France, where the firegrate surface is in general considerably larger than in this country, the fuel is very thinly and sparingly spread over the bars, so that large volumes of air are allowed to enter the furnace without coming in contact with the gases of the fuel. Now, what does this produce? Suppose certain volumes of gases create, by chemically combining, a heat of say 3000° Fahr. If other volumes of cold gases enter which create no heat, then the former must give up some of their heat to the latter. Here then is a point which must be closely examined. If every particle of oxygen could be made use of, then 75 cubic feet, or 11 lb. of atmospheric air, would suffice to burn 1 lb. of coal. But instead of this, our ordinary furnaces being so badly constructed, it is calculated that 150 cubic feet of atmospheric air is necessary for the complete combustion of every pound of coal; and the consequence is that only a very small part of the gases

enter into complete combustion, and even these are soon robbed of their heat by the other cold gases coming in contact with them. Still this 150 cubic feet of atmospheric air is only a moderate quantity per pound of coal. Very often 200 cubic feet and more enter the furnace per pound of coal, and in some cases more than 400 cubic feet of air per pound of coal is driven through the furnace, as in a torpedo-boat. There certainly may be some 3000° Fahr. in the furnace and some 1400° Fahr. in the funnel, but at what waste of fuel, and at what destruction of material and power, is this accomplished?

Out of the uptake pours one continual dense black smoke, and at night a red flame is often seen. This black smoke may perhaps be the least loss, the condensed invisible gases formed being much greater in amount; in fact, only a small quantity of fuel forced into the furnace is properly consumed, which is proved by the small quantity of water evaporated per pound of coal, which is at the best from 5 to 6 lb. of water per pound of coal. The ordinary furnace is not much better. Looking into the furnace-door where green coal is burning, the colour of the flame will show the development of heat. At the bottom of the flame there is generally a dirty red colour, a little higher red, orange, and at last on the top a yellowish white. This latter is well known to contain the greatest amount of heat, but the amount of complete combustion entering the chimney as carbonic acid is very small in comparison. The greater portion of escaping gases are oxides or condensed invisible gases, and form smoke. On the whole this will show that the combustion in the furnace is very incomplete. The yellowish-white flame from bituminous coals is giving the highest degree of heat in the ordinary furnace, but it is well known that it is by no means the greatest heat which can be obtained. By the help of the blowpipe, blowing into a burning coal, a transparent flame may be produced with a tint of bluish or greenish colour. This flame gives a much greater heat, and it may frequently be seen arising from anthracite coal or good coke. But the flame from these fuels is very short, and the heat, therefore, concentrated within a small space, which is a source of danger to the boiler-plates; and it is, therefore, no wonder that engineers, fearing to burn holes in their boilers, do not want any greater heat, forgetting that the largest part of the steam in a boiler is formed just over the bridge, and that on these few feet of plate the most and the hardest crust is formed from the solids contained in the water of which the steam has been formed. This c ıtion of heat ought, therefore, to be avoided at any t by distributing the heat over a much larger surface es it penetrates to the water and forms steam.

This result has been successfully obtained by the author's new furnace with a firebrick embankment and bridge, and which has the firebars sloping downwards to the front, with a proper guide for the air beneath the firebars, as shown in section in the diagram. A guide to the draught will help it to flow easy by a gentle sloping course from under the firebars for the better combustion of the fuel. It is of the utmost importance that all corners and obstacles should be avoided for the proper guidance of draught for the fuel to the top of the firebars. These firebars have been made to slope downwards to the front, so that the air, entering in front at the bottom of the door, and guided by the slotted plate hanging down within, acts on the burning fuel similarly to the blowpipe and produces a long, bright transparent flame with a tint of blue or greenish colour, which shows that thorough combustion is going on. In this furnace no atom of oxygen from below or from the front can escape without coming in contact with the fuel and thus producing almost perfect combustion. The damper is generally one-third open, but this is quite enough for the burning mass to draw in the atmosphere by its own gravity, and therefore not a particle of air is drawn in more than is actually consumed by the fuel, so that the heat once formed by the gases within the furnace is retained, and not reduced by a useless and damaging surplus of cold air. The slanting firebars have another very important purpose, and that is, to guide the bright flame as near as possible to the boiler-plates, and to keep it near the plates the firebrick embankment is formed about 3 feet 6 inches long, conforming to the shape of the boiler, and leaving only an 8-inch space at the front end and a 7-inch space at the back end between them. At the end of this embankment is a pocket or chamber for any heavy dust that may have been brought forward by the draught to settle in. Then comes the so-called bridge with a 7-inch space between it and the boiler, so that the flame, some 10 or 12 feet long, is obliged to remain the whole length close to the boiler-plates. Thus the area of heat penetrating the metal to form steam is at least four or five times greater than in an ordinary Cornish or Lancashire boiler.

It should be remarked that the air entering the furnace from the front at the bottom of the hanging plate is only the small quantity necessary for supply to the gases rising from the top of the fuel, chiefly after firing when the coals get warm, which opens the pores and allows the compressed volatile gases to escape in large quantities, to the amount of some 17 per cent. of their weight. These gases seldom find the oxygen required for their combustion within the furnace, as the air which enters through the firebars, and the incandescent fire, has for the most

part combined with the volume of oxygen or hydrogen to form combustion. It will therefore be seen that a further supply of air is necessary for these newly liberated gases to enter into combustion. Warm air and a forced combination of the gases, as in the present instance, of course produces the highest degree of combustion. The author would, however, caution steam users against allowing the air to enter from the front at the top of the furnace, as such air would absorb a great deal of heat, and would mostly float on the top of the burning gases, being raised by the superheated moisture which the atmosphere contains, and forming a thin layer close to the boiler-plates. Thus to some extent the heat would be prevented from penetrating the plate and reaching the water within the boiler.

And here the author may explain why it is that when the firedoor is ajar, very little smoke is visible, and that if the stoker endeavours to prevent smoke, he leaves the firedoor ajar, not knowing either the mischief or the cause and effect of what he is doing. The matter, however, is simple enough. The atmosphere requires to exert more force to get through the bars and the fire upon them, and it therefore enters more easily at the front door and produces the entry of air from below. The quantity being very small, and no condensation taking place, little or no smoke is formed.

The principle of combustion in a furnace or the combination of the gases is easy of explanation. The oxygen leaves its companion nitrogen and flies quickly to its more attractive friends carbon, or hydrogen. Still it has been proved that when some force is used to bring the two gases together a more complete combustion takes place, as for instance by the blowpipe, by which a much greater heat is then obtained. This is what the author tries to do by the blowholes in the iron plate, at any rate he is able to obtain a much greater heat than any ordinary furnace has ever produced. A Lancashire boiler 18 feet long by 7 feet diameter has generally from 30 to 36 square feet of firebars, but by the author's system there are only 7 square feet of firebars, which are 3 feet 6 inches long and 2 feet wide, of which 2 inches are lost on each end, thus leaving only 6 feet 4 inches square clear. With this small area of firegrate the author has been able to evaporate as much as 178 gallons of water per hour. The heat on the firebars has often been so great that they have melted, and a few small steam-jets have been placed beneath the bars to cool them. It appears that the air-guide under the bars compels the atmosphere to ascend
ıgh the bars, there combining with the gases, the whole
met from the front by a supply of fresh oxygen, which
increases the heat, just as two gas-jets meeting at a

certain angle will increase the illuminating power and flame. In the case of the author's furnace, besides increasing the heat, the confluence produces an extraordinarily long transparent flame.

It may here be mentioned that when firing, the mass of fuel is pushed back, and fresh coals are fed into the furnace. The heat is then so great in the furnace that hardly any red flame is visible, and hardly a vapour of smoke passes from the chimney, the damper being left open. The coal used is the commonest hard steam, costing about 13*s.* per ton. The boiler, although of the Lancashire type, is fired underneath, having been set for the purpose of burning chips and sawdust. But if this boiler was fired in the two flues the firebars in each flue would only require to be 2 or 3 feet square in area, with the embankment and bridge as shown in the section. If a couple of Galloway tubes were placed in each flue to retard the heat the author has no doubt a much larger evaporation of water per lb. of coal could be obtained with the greatest ease.

Of the many tests made, the water being measured and coal carefully weighed, the author here gives some, showing the difference of draught, water evaporated and coal used, and the area of firebars with a movable dead-plate on the top front of the bars. The first test experiment was to ascertain the smallest grate area required to produce the necessary steam for the author's works; the second was made to ascertain the maximum quantity of coal to be burned per square foot per hour, whilst the third was ordinary firing.

No. 1, September 2, 1884. Test time, 4 hours, with damper about one-third open and 4 feet 1 inch square of firebars, beginning with 40 lb. steam pressure, but losing during the four hours 25 lb. pressure, burning 3½ cwt. of coal and evaporating 492 gallons of water, or 123 gallons with 98 lb. of coal per hour, equal to 12½ lb. of water per lb. of coal.

No. 2, September 8, 1884. Time, 3½ hours; 6 feet 8 inches square of firebars, damper full open, 49 lb. steam pressure, and blowing off all the time by a 1-inch steam-pipe from the boiler, besides using steam for factory use, firing about every half hour, with 1 cwt. of coal, 7 cwt. in all used, evaporating 605 gallons of water or 173 gallons with 2 cwt. of coal per hour, or nearly 7¾ lb. of water evaporated per lb. of coal. In the first hour the coal consumed per square foot of firebars was 41 lb., but afterwards the bars got foul and the average was 33½ lb. of coal per square foot of firebars.

No. 3, September 29. Time, 4 hours; test made with 4 feet 8 inches square of firebars, damper not quite half open, steam pressure 45 lb., afterwards went up to 50 lb., steam blowing off

evaporating 451 gallons of water and burning 3 cwt. of coal, or 112¾ gallons of water with 84 lb. of coal per hour, giving 13¾ lb. of water per lb. of coal. It should be remarked that the boiler has not very high steam-space, and will prime a little when worked at a high pressure.

The first and second trials afford a striking illustration of the waste going on with a forced draught. In the first instance the damper was only about one-third open, and the heat produced must have been as great from the small quantity of coal supplied as from the larger quantity of coals forced into the furnace with the damper quite open and a stronger draught. If the latter had produced a greater heat, then a larger quantity of water ought to have been evaporated per pound of coal; and it stands to reason that in the first instance the flame had more time to perfectly develop itself. Another important point is that there was time for the heat to penetrate the metal for forming steam, the quantity of which must have been considerable, whilst in the second trial more than double the quantity of fuel evaporated only 40 per cent. more water, therefore 37 per cent. of the entire supply of coal must have been lost, or the heat produced by it carried away into the chimney. This furnace proves that it is not that a great quantity of solid or gaseous fuel is requisite to produce a high degree of heat, but that it depends entirely on the proportion or volume of gases and the guidance of such gases, which produce a force tending to their perfect combination.

At the meeting of the Iron and Steel Institute at Chester, in September last, Mr. Frederick Siemens read a paper on regenerative gas furnaces, in which he stated that hitherto it had always been considered that the first condition of furnace working was to make the space to be heated as small as possible, and to bring the flame into intimate contact with the lining and with the material under treatment, but he had satisfied himself that in such gas furnaces the flame should only radiate over the material to be melted, and should not come into actual contact with it. Further on he observes, that it must be borne in mind that in a gas furnace the amount of fuel used does not depend so much on the intensity as upon the quantity of heat required, whereas in solid-fuel furnaces large quantities of fuel must be consumed to obtain a high temperature. Again, he observes that the actual flame is not allowed to come in contact with the material, the interruption of combustion by the interposition of solid bodies always tending to injure them, and he thinks the new system propounded by him will be applicable to boilers, and will produce a great saving, Mr. I. Lowthian Bell doubted a saving of 25 per cent. The important points in this

paper in regard to boilers are that the flame from the solid fuel is not to come in contact with bodies, and that a large quantity of solid fuel is required to produce a great heat. The first point could only be carried out with anthracite coal or coke, as the space for the flame of bituminous coal would be too great or high for the present arrangement of steam-boilers; and as to the second point, the author has proved by his system that it does not require a large quantity of solid fuel to produce a great heat. Moreover, the transparent flame does not mean the development of combustion in the flame, but demonstrates the highest perfection of combustion at present known. Therefore this flame can afford to impart heat to solid bodies without deteriorating the remaining flame.

Another important point occurs in Mr. Siemens' reply to the discussion which took place upon his paper. He stated that, under ordinary conditions, imperfect combustion took place in the immediate neighbourhood of the boiler surface, owing to the local cooling of the gases, and that the result was the formation of a smoky layer, which diminished the effect of radiant heat. He stated, however, that on the whole he considered that the electric theory explained what took place. According to this theory, flame was nothing but a series of electrical discharges, very minute but very numerous. According to the motion theory, the introduction of a solid body into the flame limited the motion of the particles, and so caused decrease of temperature and incomplete combustion.

What this electric theory may be the author does not know, but according to science, sound, flame, light, and electricity are all caused by vibration or waves; and Dr. Tyndall, in speaking of sound-waves, has said that the molecules bombard the walls or solids and are repelled. Well, then, if a part of a sound-wave strikes against a woollen fabric, and another part of the same sound-wave strikes against a pine lining or a steel plate, the result is that in the first instance the sound-wave is absorbed and certainly not repelled, whereas the other part of the wave is repelled as many times as the note contains vibrations. It is therefore the author's opinion that the vibration of the flame is communicated to the boiler-plate, or to any other substance, and that such part of a flame is absorbed, leaving only a slight degree of heat behind, but the other part of the flame has the same vibration or heat as before. Still this remaining flame may be absorbed by degrees in its passage, and leave very little heat behind. This would account for the smoky layer of which Mr. Siemens speaks. It is well known that almost every flame will produce invisible vapour, and if the heat is withdrawn from such vapour, then the vapour will con-

dense and become visible, and float on the top, and certainly prevent the flame doing its duty to the boiler in some degree. Still, if Mr. Siemens' statement that the radiating heat from a flame is so much greater than the flame itself be correct, then the estimated heat produced from coal must be utterly wrong.

The author thinks there can be no more striking proof of the correctness of his theory than the fact that the flame produced in his furnace, and the heat arising therefrom, do their full work, leaving only a minimum of heat behind. It is of course a natural result that the more complete the combustion of fuel, so much greater the heat of the flame must be, and it stands to reason that the greater heat will more easily penetrate the metal and be absorbed by the water within. This will go on until all the flame is so absorbed as to leave very little unconsumed gases behind, except some condensed vapour. This is proved in the long flue towards the chimney, where the heat has generally been from 290° to 300° Fahr. in all other tests or trials. But in the author's furnace there is no more than 200° Fahr. of heat at 1 foot from the damper, and half a degree less at 20 feet distance from the damper in the flue.

Two tests have been made with this furnace by independent engineers, one by Mr. D. K. Clark, and the other by Mr. W Schönheyder. Mr. Clark's test was made on November 10, 1884, and the following are the leading results as stated in that gentleman's report to the author:—

RESULTS OF TEST.

Temperature of atmosphere	54° Fahr.
Weather	N.W. breeze. Fair.
Duration of test	6 hours 50 minutes.
Coal consumed	721·5 lb.
Coal consumed per hour	105·6 lb.
Coal consumed per square foot of firegrate	21·86 lb.
Number of firings	14
Average interval between firings	29·3 minutes.
Weight of fuel per firing	51·5 lb.
Clinker produced	14·5 lb.
Ash produced	25·0 lb.
Clinker and ash residue	39·5 lb.
Clinker and ash per cent. of coal consumed	5·47 per cent.
Average pressure maintained in boiler per sq. inch	34·0 lb.
Temperature of burnt gases in flue to the chimney	200° Fahr.
Average temperature of feed-water	70° Fahr.
Quantity of water consumed	150·8 cubic feet.
Quantity of water consumed per hour	22·08 cubic feet.
Quantity of water consumed per sq. foot of firegrate	4·57 cubic feet.
Quantity of water consumed per lb. of coal consumed	13·02 lb.
Quantity of water consumed per lb. from and at 212° Fahr.	15·11 lb.
Quantity of water consumed per lb. of combustible	13·78 lb.
Quantity of water consumed per lb. from and at 212° Fahr.	15·98 lb.

Mr. Clark states that the steam proved to be dry, and there was no evidence of priming in any way. The broad result here is an evaporation of 13·02 lb. of water per pound of coal from a temperature of 70° Fahr. The test was made under conditions of slow combustion, only a small proportion of steam being used during this trial for driving the machinery in the author's works, most of the hands being absent on a holiday.

Mr. Schönheyder's test was made on November 20, 1884, and the following are the tabulated results given in the report made by that gentleman to the author:—

RESULTS OF TEST.

Length of test	8 hours 25 minutes.
Water withdrawn from tank	12,857 lb.
Water withdrawn from tank per hour	1,531 lb.
Coal thrown into furnace	1,120 lb.
Coal thrown into furnace per hour	133 lb.
Mean temperature of feed water	74° Fahr.
Mean pressure of steam (27 lb. to 40 lb.)	35 lb. per sq. inch.
Mean temperature in back flue (348° to 376°)	356° Fahr.
Mean temperature of atmosphere	44° Fahr.
Water per square foot of heating surface per hour	2·66 lb.
Coal per square foot of grate per hour	29·6 lb.

The evaporation would therefore appear to have been at the rate of $\frac{12857}{1120} = 11{\cdot}48$ lb. of water per lb. of coal from 74° and at 35 lb. boiler pressure.

The equivalent evaporation from and at 212° would be 13·39 lb. of water per lb. of coal.

At the conclusion of the test 40 lb. of ashes and clinkers were left, equal to barely 4 per cent. of the coal used; 13 lb. of cinders were also left, but evidently of small value.

Thus far the author has quoted Mr. Schönheyder's own words. He will only add that that gentleman's test was made under the conditions of quick combustion, that is, when the author's factory was in full work and the boiler supplying steam to drive all the machinery. Mr. Schönheyder also states in his report that the combination of the furnace arrangements assists to cause an intense heat and very perfect combustion, the top of the chimney being, as a rule, during his test quite clear of smoke.

In his opening remarks the author showed, on the authority of careful scientific investigators, that pitting and corrosion were due to the action of cold air impinging on the boiler plates.

As in the author's furnace cold air is carefully excluded from direct contact with the boiler, it follows that, the cause being

absent, the effect is obviated, and that therefore pitting and corrosion cannot occur in boilers properly set and fired upon the blowpipe-flame system.

In conclusion, the author would simply state a well-known fact with regard to the burning of ordinary coal-gas, which will serve to make the matter clear to any one who may be in doubt as to how such high results are obtained in the author's furnace as compared with ordinary systems. Five cubic feet of gas burned in an ordinary gas-burner gives out a known and definite quantity of heat. Five cubic feet of gas burned in a Bunsen burner, in contact with a definite and properly regulated quantity of atmospheric air, developes a far greater proportion of heat. In like manner a pound of coal burned in the ordinary way will give out a certain amount of heat, but a pound of coal burned with the assistance of the blowpipe developes a great excess of heat. This simple statement needs no comment from the author. It forms the keynote to the successful results of the furnace he now has the honour to bring under the notice of the Society.

DISCUSSION.

Mr. J. Head said the principle of heating by radiation, introduced by Mr. Frederick Siemens, was entirely different from, in fact the reverse of, that which had been developed in the paper. In the furnace described by Mr. Engert heating by contact might be said to have been carried to the furthest practicable limit, and he claimed that result, for he said that in order to obtain the best results he considered it necessary to get the flame as close as possible to the plates of the boiler; and, for the purpose of supplying a theory of combustion under such conditions, flame was compared to waves of sound which did not produce their full effect until they came into contact with surfaces. Mr. Frederick Siemens had adopted the opposite course, maintaining that if flame be brought into contact with any solid substance combustion was impaired. He (Mr. Head) had had an opportunity of proving the correctness of Mr. Siemens' views when in Wales recently by inspecting the working of some Siemens Open-Hearth Steel Melting Furnaces, taking heavy charges of metal. Those furnaces, as was well known, were regenerative gas furnaces with the flame traversing [illegible] chamber over the metallic bath alternately [illegible] of the chamber. Each furnace had three doors, [illegible] and one in the middle. The doors were [illegible], the first one being at the end from which [illegible] time coming into the furnace, where the [illegible] quite clear, contact with solid substances [illegible]; the next door opened was the centre

one, and there being at that point a slight contact between the flame and the metal, the flame was certainly impaired to some extent; but when the third door was opened through which metal had recently been charged into the furnace (there being a large ingot mould weighing probably 7 or 8 cwt. on which the flame struck) not only was the flame found to be impaired, but smoke was produced in abundance. The managers of the works not having before examined a furnace in that manner were somewhat astonished at the result, which, however, proved the correctness of Mr. Frederick Siemens' conclusions. In firing furnaces it was found necessary to bring the gases and the air supporting combustion together at about the same temperature; if cold gas and hot air, or hot gas and cold air, were brought together bad combustion would ensue, but if they combined at approximately the same temperature a good combustion free from smoke would be the consequence, provided that other necessary conditions were attended to.

Mr. Head exhibited a diagram of a boiler heated according to Mr. Siemens' design, which, he said, was not to be fired with solid fuel but with gas. The fuel was converted into gas in a separate apparatus and brought by a flue to the boiler, where it met heated air brought through an adjoining flue. The gas and air on meeting would burst into flame, which was prevented from coming into contact with the plates of the boiler by means of rings inserted in the internal flue of the boiler, at both ends and in the middle. Only after the flame was exhausted at the end of the internal flue of the boiler were the heated gases brought into contact with the boiler-plates while passing through the other flues, and they were also made to heat, by conduction through brickwork, flues through which the air supporting combustion travelled on its way to meet the gas. The result of working a boiler in that manner, instead of by contact of flame as formerly, Mr. Siemens had found to be a saving of 25 per cent. of fuel, which was due to perfect combustion of the gas, the flame not being quenched by contact with the comparatively cool boiler-plates. In the paper which had been read he observed the absence of a very important data, namely, the analysis of the chimney gases. The determination of the proportion of combustible elements and the proportion of free oxygen present in chimney gases was a necessary test of efficiency attained in the firing of boilers and other furnaces.

Another drawback to the use of flame in contact with boiler-plates was the deterioration of the plates caused thereby. If there was any sulphur in the flame it would act injuriously upon the plates, probably causing the spots of dark-coloured substance referred to in the paper, which were supposed to be

oxide of iron, but which he thought were more likely to be sulphide of iron.

As to the electrical theory, as described by Mr. Siemens at Chester, that gentleman did not claim it as emanating from himself. It was necessary, in order to explain the satisfactory results obtained with the method of heating by radiation, that some theory of combustion should be adopted, and Mr. Siemens had selected the electrical theory because that was the one by which those results could be most readily explained to a meeting, but they were equally susceptible of explanation by adopting another theory. As Mr. Engert in his paper had given an incomplete report of Mr. Siemens' remarks, he (Mr. Head) asked to be allowed to read them: they were as follows:—"To explain why combustion was interrupted when it met with solid substances, and why the solid substances suffered so much from the action of flame—not from heat—and why flame had such a radiative power in its first stage and none in its second, it was necessary to have recourse to one of the theories of combustion, and he had adopted the electrical theory as having the greatest probability of proving to be the true one. According to this theory flame was made up of a multitude of small lightning explosions, very minute but very numerous, and it was easy to understand why solid bodies if brought into such a flame would obstruct its action, they having the effect of precipitating the gas by adhesion and attraction. Consequently the gases which were considered to revolve were obstructed in their motion, and not being able to move, combustion could not continue, at least in those parts nearest the opposing surfaces. The result was that there was less intense heat and that smoke was produced instead, enveloping the obstructing surfaces; and so radiation could not act because it could not penetrate the cloud of smoke in which the flame was enveloped. This lightning action accounted for the fact that bodies were so soon destroyed when exposed to the action of flame, while the presence of innumerable electric flashes accounted for its radiative power. Flame radiated heat better than the solid surface of a furnace, because it radiated right through and from all sides, while a solid surface radiated only in one direction; the result was that with the diameter doubled the flame radiated four times as much, while the solid surface only radiated twice as much heat as before. In the second [illegible] there was less chemical action. No free carbon [illegible] it was only natural that that part of the flame [illegible] sess any strong radiative power. The principle [illegible] hich he (Mr. Siemens) advocated could be used [illegible] ons in which smoke would otherwise be pro- [illegible] this way could works be extended without

encountering serious opposition. It was to be borne in mind that flame in its first stage required free space and emitted its heat by radiation only, while in the second stage the heat was supplied by contact. The new method of heating could be almost universally applied and would tend much to do away with the smoke nuisance."

He (Mr. Head) would mention that boiler furnaces had so far not formed part of Mr. Siemens's work, but the late Sir William Siemens, and Mr. Frederick Siemens, had done a great deal in furnaces of other kinds which consumed more fuel than boiler furnaces. They had found heating by radiation to be a great improvement, having given them many advantages.

Mr. W. SCHÖNHEYDER said it appeared to be Mr. Engert's opinion that forced combustion must necessarily cause a waste in many boilers, and locomotive and torpedo boilers were specially referred to as being constructed so as to cause waste of fuel on account of the forced combustion. A locomotive boiler *per se* was about the best boiler we had. With the forced combustion combined with the general arrangement, and possibly some other action which was not explained, there was a very high evaporation in locomotive boilers, taking into account the comparatively small amount of surface which there was for evaporation. Mr. Webb of the North Western Railway had found 10¼ lb. or more evaporated per pound of coal in some of his boilers, reckoning from and at 212°. That was a remarkable performance. If there was a low evaporation per square foot of heating surface per hour it was a very easy matter to get economy, but when the evaporation was quick economy was difficult to obtain. The same remarks applied to torpedo boilers. Mr. Engert said in his paper that only 5 lb. or 6 lb. of water were evaporated per pound of coal in torpedo boilers. In several torpedo-boat tests of which he (Mr. Schönheyder) had notes, 7 lb. or 8 lb. and even 8⅓ lb. of water had been evaporated per pound of coal. The reason why the evaporation was low in torpedo boats was that the circumstances were such that they must produce an immense amount of steam in a small space. The heating surface was therefore small and a large amount of heat was lost by the chimney, but taking the small surface into account, torpedo boats really beat the locomotives in respect of economic evaporation. Mr. Engert had remarked that when coal was burnt by means of a blowpipe it gave a much larger amount of heat than when it was burnt in the ordinary manner of slow combustion. He thought Mr. Engert rather meant that they got a greater intensity of heat and not a greater quantity. The tests made by Mr. Engert in which he obtained an evaporation of from 7 to 12 lb. were tests of only four hours' duration. He (Mr. Schönheyder) had no

hesitation in saying that with a large land boiler, having a large surface of water, and storing in the brickwork a considerable amount of heat, a four hours' test was far too short, in fact it was valueless. It was very difficult to observe the exact level of the water to a great nicety, and a small error in that respect made a great difference in the results. In the test which had been made by Mr. D. K. Clark, the quality of the coal used was not stated.

Mr. ENGERT said the coal was the same as in the other tests.

Mr. SCHÖNHEYDER said that an evaporation of 15·11 lb. of water per pound of coal was most difficult to obtain from and at 212°. It must have been a very first-class coal to have produced such an evaporation. The highest theoretical evaporative power known was 15 lb. or 16 lb., and he could not understand how such a high result could have been obtained in the test referred to. The test which he (Mr. Schönheyder) carried out at Mr. Engert's works showed apparently 13½ lb. of water evaporated per pound of coal. He did everything to obtain as accurate a result as possible. But now came an unpleasant fact. He took fair average samples of the coal; but those, when subjected to the calorimeter test by Mr. Hartley, showed only a total evaporative power of 12·8 lb. of water from and at 212°. He could not account for such a high evaporation as that shown by his (Mr. Schönheyder's) test at the works. Possibly there was some leak in the boiler, or the steam might be wetter than he supposed. The loss of heat in the flues was 356°. That would cause about 10 per cent. of loss, and there would be some loss from radiation. These two together would give a total loss of, say, one-eighth, so that the greatest possible evaporation under those conditions would be a little over 11 lb., and yet there was apparently an evaporation of over 13 lb. As to the Bunsen burner, he believed that the statement that it gave more heat than an ordinary burner had been conclusively contradicted. The great advantage of the Bunsen burner was that it produced more perfect combustion, and smoke was avoided. He must say that the combustion in Mr. Engert's furnace was very perfect, and there were good reasons for it. The furnace was surrounded on three sides by brickwork, and the doors were arranged in such a way that the air was brought into immediate contact with the fuel at the bottom. The arrangement in that respect was similar to that made in the Argand gas-burner by Sugg and other makers. Hardly any smoke was to be seen issuing from the chimney. He did not agree with Mr. Hen that it was necessary to avoid bringing the flan with the boiler. He did not think that,

if combustion had been once perfectly effected, any loss could result from the flame coming into contact with the boiler. With reference to Mr. Siemen's furnace, he should imagine that the bottom flue would in time become coated with dusty matter, and that transmission of heat would be thereby prevented. With reference to Mr. Head's statement, that the efficiency of a furnace might be reduced a quarter or a half by want of attention in stoking, he (Mr. Schönheyder) thought that in such a case as that the stoking must be very poor indeed. If anything like a quarter or a half was lost through bad or intermittent stoking, they would never be able to obtain so high a duty as 78 per cent. of the total calorific power of the fuel.

Mr. HEAD, in reply to Mr. Schönheyder's suggestion as to the flue in Mr. Siemens' boiler being coated with dusty matter, said there was no dust arising from the combustion of gaseous fuel. All the dust, or ash, of the coal remained in the gas producers, from which it was easily removed while continuing to supply gas for heating either furnaces or boilers. With reference to his previous remarks as to efficiency of a furnace being reduced by want of attention in stoking, he said he had referred to Rankin on that subject, and it was from that authority he gathered that the loss due to bad stoking varied from a half to a quarter of the calorific value of the fuel employed.

Mr. F. W. HARTLEY said that he tested the coal to which Mr. Schönheyder had alluded by means of the Thompson calorimeter, an instrument with which he had worked very much, and with which he had hitherto obtained most satisfactory results. Careful experiments proved that the highest result which could be got from the sample of coal delivered to him by Mr. Schönheyder was equal to 12·8 lb. evaporative power. There were difficulties in the way of burning certain sorts of coal in the calorimeter. Very hard coals and very soft coals were somewhat troublesome, but under certain conditions which could be known only by experience with the instrument, fair and proper indications were realisable. The most difficult material was coke, but it could be burned. He had frequently found, however, that the actual duty realised from ordinary gas coke was equal to the calorific power indicated by the instrument. It was impossible for him to believe, after the many years of experience he had had with the Thompson instrument, that its indication in the present instance was wrong, or that he should have been in error in making the tests. So much confidence existed in the instrument, that in Wales and in the north of England and in Italy it was widely used. In fact in Italy the railways founded the price to be paid for coal entirely

upon the indications afforded by the calorimeter. In a pamphlet relating to Thompson's calorimeter it was stated among some general observations that the lower the temperature of the water employed, the higher were the results indicated. When he was testing the coal for Mr. Schönheyder, he had the water at a temperature of about 54°, which was an exceedingly favourable temperature. It was further stated that a difference between the temperature of the water and the temperature of the air might cause an error in the indications. An error to the extent of ¼° Fahr., which was equivalent to ¼ lb. of coal, might be occasioned by a difference of 10° Fahr. In practice, however, it was usual to make a preliminary test, then to start with the fresh charges of water at as many degrees below the temperature of the air as the water was likely to be raised above the air temperature. He could not pretend to dispute the accuracy of Mr. Schönheyder's test, but it was certainly peculiar that such discordance should exist between the experimental and the working determinations. Possibly after all care in selecting, the sample rendered to him (Mr. Hartley) was not of the fair average quality.

Mr. SCHÖNHEYDER explained the means adopted by him in order to secure fair samples of the coal actually employed in stoking to send to Mr. Hartley.

Mr. PERRY F. NURSEY said it appeared that the meeting had before it something of a puzzle on the present occasion. They had had described to them a boiler and furnace which had been carefully tested by two independent engineers, and which gave abnormally high evaporative results. Mr. Hartley had tested the fuel by means of an apparatus which had hitherto given satisfactory results, which results coincided with ordinary steam-boiler practice, but which in the present instance did not agree with the results of the tests made by Mr. Schönheyder and Mr. Clark. It should be remembered that in Mr. Engert's boiler coal was being used under a new set of conditions, and it had occurred to him (Mr. Nursey) that the coal was giving higher evaporative results than were ordinarily obtained simply on account of the altered conditions under which it was burned. It therefore became a question for Mr. Hartley and others to consider whether it was not time that there should be some alteration made, leading to an advanced method of testing coal, in order that the results might possibly be made to agree with the advanced practice which appeared to be successfully embodied in the furnace before the meeting. Mr. Engert had placed a new problem before them, and he (Mr. Nursey) considered it to be a very ingenious problem. He had inspected Mr. Engert's furnace, and certainly he had never seen a better

flame or one more nearly indicating perfect combustion. The results which he witnessed were certainly very remarkable. It was before the meeting that both Mr. Clark and Mr. Schönheyder had reported very high evaporative results, and although the latter gentleman questioned his own figures, he could only do so upon the hypothesis that a secret leak had escaped his vigilant eye, or that the steam was not so dry as he thought it to be when testing the boiler.

Mr. H. OLRICK said that the question of the production of smoke suggested by Mr. Head appeared to be at variance with the accepted theory of what smoke really was, and, as Mr. Schönheyder had pointed out, it was difficult to understand that if perfect combustion had been obtained, that the gases could produce smoke by simply impinging on the plates of a boiler. With regard to Mr. Engert's boiler, he thought the evidence went to show that the duty obtained from the combustion of the coal was simply impossible, and the only explanation was, that there must have been some leakage in the boiler or some cock left open. Looking at the construction of the boiler, and making due allowance for the fact that the coal was burned in the best possible manner, namely, with a fire-brick casing around it, he could not see that any other boiler, working under the same advantageous circumstances, would not give as good results as Mr. Engert's boiler. The test made by Mr. D. K. Clark was more astounding than that made by Mr. Schönheyder, as it showed a duty greatly in excess of the theoretical value of the coal.

Mr. CHARLES GANDON said he agreed to a very great extent with Mr. Olrick. He was certainly at a loss to understand what there was in the construction of the Engert furnace which would produce such good results. The furnace gave rapid combustion and a quick draught, and so far as his experience went those conditions were antagonistic to the obtaining of good results from the amount of fuel consumed. He had always been under the impression that the best way to get the greatest work out of fuel was to keep the products of combustion the longest time possible in contact with the surfaces to be heated. Mr. Engert's furnace was certainly well described by the title of a blowpipe-flame furnace. A blowpipe gave very high results as regarded intensity, but they could not obtain the greatest amount of heat from it. There might be something in the setting of the furnace to account for the high results. When furnaces were being experimentally tested, a great deal of attention was paid to the putting on of the fuel and to the working of the dampers, and the high results claimed for the Engert furnace might be partly due to that circumstance.

Mr. W. Wood asked from what part of the boiler steam was taken, as that was an important point.

Mr. Engert, in reply, said that Mr. Head had been to some extent answered by Mr. Schönheyder. He (Mr. Engert) was quite of the opinion that the flame, once completely formed, could not be reduced in any way, or it would be absorbed and cease altogether. The evaporative efficiency of his boiler seemed to puzzle many of the speakers. He could only say that he had the more intense heat of a blowpipe to deal with. Steam was taken from the top of the boiler, but not by an antipriming pipe. The boiler was fired underneath, and he found that when the air was properly guided from below by a sloping surface, combustion was much more perfect than with a horizontal surface and sharp angles. Every engineer tried to diminish the firegrate surface and to increase the heating surface, and to have a better and thicker fire on the grate. His boiler had been set about eight years ago and no alteration had been made in it; but in August last it was thoroughly examined by the Boiler Insurance Company and there was no leakage whatever found in it. A very small leakage had occurred in the front seam, but it was so small that it could do no harm, and it had been caulked. Mr. Schönheyder spent a whole day in carefully examining the boiler and everything about the place, and he had no doubt satisfied himself that there was no deception in the matter. Any one else was at liberty to examine into it for themselves.

The President said that the boiler which Mr. Engert had brought under the notice of the meeting was one where a large furnace had been reduced in area and the rate of combustion accelerated, so that the temperature of combustion was increased and a comparatively enlarged heating surface secured. That condition raised the problem of quick, as against slow, combustion, and so rather complicated the consideration of such peculiar merits as Mr. Engert's furnace might possess. In reference to Mr. Schönheyder's remarks about locomotives, he (the President) had recently seen a new locomotive in America, which was being built for slow combustion, having a furnace 8 feet wide. The subject of boilers and the evaporative power of coal was one which was in a state of progress at the present time, and he could not help feeling that in the course of a few years they would have some results which were unexpected, and that eng[illegible] would eventually produce new systems and much b[illegible]lts than they had at present.

WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

MAR 4 - 1942